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SHOULD HUMANISTIC-SOCIAL STUDY BE MADE ENGINEERING EDUCATION? *Alfred C. Ames* 543

A GREAT RESPONSIBILITY. *L. K. Sillcox* 547

SHOULD ENGINEERS STUDY STATISTICS? *Holbrook Working* 557

CREATIVE ENGINEERING RESEARCH: ITS STIMULATION AND DEVELOPMENT. *W. R. Woolrich* 565

ENGINEERING STUDENT ENROLLMENTS GROWING, BUT FAR FROM NORMAL. *W. B. Plank* 572

A NOTE ON FOREIGN SERVICE AND THE FOREIGN STUDENT. *J. K. Finch* .. 576

REPORT OF THE ENGINEERING COLLEGE RESEARCH ASSOCIATION'S COMMITTEE ON LEGISLATION. *C. E. MacQuigg* 579

SPECIALIST FOR ENGINEERING EDUCATION APPOINTED 587

SECTIONS AND BRANCHES 587

GEORGE WESTINGHOUSE CENTENNIAL 589

NEW MEMBERS 590

COLLEGE NOTES 591

GEORGE WESTINGHOUSE AWARD IN ENGINEERING EDUCATION 595

MECHANICS DIVISION 597

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Should Humanistic-Social Study Be Made Engineering Education?

By ALFRED C. AMES
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What is "engineering education"? To some the phrase signifies an education in subject matter and in methods peculiar to, or at least especially characteristic of, engineers. To others, "engineering education" means the education of persons aspiring to become engineers.

Before we can consider whether or not humanistic and social studies should be made "engineering education," it is needful to define that last term. We need to ascertain (1) what is peculiar to engineering, and (2) whether "engineering education" means education peculiar to engineering, or education of prospective engineers.

I

We hear occasionally of "engineering ways of thought," "the engineering method," and even viewing literature, music, and art through "engineering eyes." Just how "engineering eyes" focused on literature differ from the eyes of other human beings I do not pretend to know, but a recent contributor to these pages[1] has defined "the engineering method" as consisting of four stages: defining the problem, planning the treatment, executing the plan, and checking the work. Doubtless that is the engineering method—and also the method of problem solving in *any* field of human intellectual activity. It is simply the standard heuristic method, and may be found conveniently stated and developed in the end papers of Gyorgy Polya's recent book, *How to Solve It*. So far as I can see, there is nothing distinctively engineering about this method.

Thomas Henry Huxley, that great champion of scientific education, began his most famous essay, "The Method of Scientific Investigation," with the unequivocal and modest statement, "The method of scientific investigation is nothing but the expression of the necessary mode of working of the human mind." He proceeded to assure his lay audience that they daily employed deductive and inductive reasoning. Is the scientist or engineer entitled to claim as exclusively his own the operations of common sense and right reason? Would it not be as becoming for a teacher of English composition to tell a teacher of mechanical engineering that he should use "the rhetorical method," the "writer's ways of thought," in his engineering work, as it is for an engineer to exhort an English teacher to use "engineering methods"?

[1] Prof. Elliott Smith, "Can Humanistic-Social Study Be Made Engineering Education?" *Journal of Engineering Education*, 36 (Oct., 1945), 136.

If by engineering education is meant *distinctively* engineering education, let us honestly exclude therefrom all logic, all literature, all basic language skills, all fundamental concepts in the social sciences, all mathematics and other "pure" science. If we are to proceed on the premise that only material pertinent to engineers and also not pertinent to other collegiate students is to have a place in our curricula, we shall have to exclude everything that differentiates a college of engineering from an unabashed trade school. What is distinctively engineering and irrelevant to other pursuits and functions is more limited than some people are willing to admit. One cannot make a college curriculum out of it.

If "engineering education" means education of prospective engineers, the criterion of relevance must be not applicability to exclusively engineering functions, but value to persons whose profession is to be engineering. Let the champions of a thoroughly distinctively engineering education admit they do not have a monopoly on sound reason, by all means. Let them recognize further that their prospective engineer has a private life and a civic life as well as a strictly professional life to lead, and that the two former even have some bearing on the last. If this recognition were forthcoming, we should hear no more aggressive demands that every non-technical teacher of engineering students must show a peculiarly "engineering" value for every aspect of his subject.

As a matter of fact, it is the champion of a rigorously distinct "engineering education" who perhaps has most occasion to show cause why he should not be censured. If he has his way, what will be his effect on the education of engineers—on students, on faculties, on administrations, on society? In so far as he now has his way, what effect is he having?

II

The engineering student is not necessarily a monomaniac devoid of any interest other than a narrowly defined engineering education. He is, after all, a human being. If you prick him, he will bleed. Usually, he is young, in the late teens or early twenties. Often he has an unusually alert mind. He is still discovering the world, especially the world of ideas and intellectual and moral values. He does not want to be immured in a narrow cell of peculiarly "engineering" education. When a senior engineering student in a state university says, as I have heard one say, "I know less about nearly everything (except electrical engineering) than I did when I entered college," he is not boasting. He is voicing a justifiable grievance.

Even if the students should demand nothing but intense specialization, even if more than a few had these severely limited aptitudes and interests sometimes falsely attributed to all, should they be humored? Just this week an engineering student told me he was planning to leave college at the end of his freshman year and take night school courses in mathematics and electrical engineering, his only vital interests. As a candidate for a degree, he complained, he was being coerced into taking chemistry and, next year, physics. Will anyone maintain we should adjust curricula to such partial personalities, be they one or many? Fortunately for everyone, they are, I believe, few. With continuing sound educational policies, their number can be further diminished.

We who are professionally engaged

in the education of engineers should have a more mature and enlightened conception of suitable education than can be expected of our undergraduates. As is characteristic of the human method of determining causes of effects, we are obliged to proceed in our educational plans by elimination of irrelevancies. As causes favorable to the development of self-respecting, reasonably well developed human beings practicing the engineering profession, we can eliminate, I believe, a course of study that produces satiety—a muscle-bound "engineering" intellect that balks at the thought of engineering. We can eliminate a course of study that, so far as it is able, isolates the student from art, music, literature, awareness of the past, political insight, and social concern, except as these may be capable of exploitation for vocational advantage. We can eliminate the wrenching of the course of study into a discipline that inculcates and encourages contempt for and ignorance of studies and interests that are not peculiarly "engineering education." Every moment that is given to non-essential, peripheral tricks of a trade is stolen outright from time that should be dedicated to the end of all higher education: the progressively thorough introduction of the student to important accumulated human knowledge and skill and insight, and the progressively thorough liberation of the student from clumsiness and ignorance and error.

III

The insistence that every course in the curriculum must be made "engineering education" is a demand upon faculty members in humanistic-social departments that they are ill prepared to satisfy. Our teachers of English and history, for example, are almost always graduates of liberal arts colleges and of university graduate schools. Their professional training has been that of teachers and scholars in the fields that they "profess." They are professors of English, etc., *not* professors of engineering. They have not been prepared by education or experience to strain after analogies with or allusions to peculiarly technological subjects. Until the engineering schools start producing their own teachers of "engineering-psychology" and "engineering-literature," they must consider as part of the data what the liberal arts colleges and graduate schools have and have not done to those who teach psychology and literature to engineers.

But even if they could, *would* faculty members in non-technical fields be willing to subordinate themselves, the disciplines they profess, and the students before them to the demands of a totalitarian "engineering education"? It is reasonably clear that self-respect and self-interest alike would require rejection of such subordination. No man of standing as a teacher and scholar in letters or the social sciences is willingly going to let himself be identified with a practice that filters all his subject matter through peculiarly engineering preoccupations. He has faith in the importance of his field for human beings, be they engineers or agriculturists or pharmacists, and if he loves teaching he is going to be eager to introduce his students to the good, the true, and the beautiful in his field of special competence. Not only has such a man his own values and convictions to consider; he has a professional reputation to maintain. He is a member of a learned profession, that of teachers and scholars in his field. If he values his professional standing, he will never consent to a distortion of his work that

would unfit him, in fact or in appearance, for teaching in universities or non-engineering colleges.

IV

Ultimately, the administrators of colleges of engineering have to decide what they want in the quality of humanistic-social studies in their institutions. At one extreme, they can zealously endeavor to attract and to retain a distinguished faculty in letters and social sciences—men who will stimulate and instruct their students, men who will substantially contribute to the reputation of their schools. At another extreme, administrators can fill faculty positions with mediocre hacks, tiresome to their students, dissatisfied with themselves, obsequious to administrative suggestions that they should never distract their students' attention from peculiarly engineering education. "What do you want? Pay the price and take it."

Our students in engineering colleges are in large part youths of high and varied capabilities. They often pay unusually high tuition. They deserve the best of instruction. Is the administrator honest with the students if he puts before them instructors who present without enthusiasm or competence an ill-digested and adulterated mess of hyphenated subject matters? Our teachers of humanistic-social studies in colleges of engineering deserve some consideration, also. Is the administrator honest to all his staff if inter-departmental meddling is encouraged, if attacks on non-engineers on our campuses are launched, if discrimination in salary and recognition is the ex-officio lot of hapless teachers who cannot escape? Is the administrator serving the good name of his institution if he helps create a situation that repels and alienates ambitious and able teachers and that gives other collegiate institutions justification in looking down on the quality of any of the work done in the engineering college?

One of the platitudes of our time is that our mastery of natural forces has outrun our development of humane values and of ethical and social insight and responsibility. Science and technology have placed explosives in the hands of a society still dangerously infantile and unregenerate. The production of purblind and unimaginative technicians is no great service to the world. It has been a well authenticated educational tradition that humanistic-social studies, more than scientific-technical ones, are or can be helpful in meeting the greatest deficiency of our civilization. If this be true, it is not desirable that humanistic-social studies should be engulfed in colleges of engineering by peculiarly engineering concerns. Rather it is needful that humanistic-social studies be accorded the independent status and dignity commensurate with their mission in the education of engineers.

A Great Responsibility*

By L. K. SILLCOX

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Will it work? Will it pay? There was a time when an engineer might possibly have felt his responsibility was over after having answered these two questions regarding an engineering problem. Yet actually at no time could he rightfully have been satisfied with these answers alone. Nor would his profession, with its ever increasing emphasis on engineering achievements and their social results, be satisfied. Increasingly, all groups—educators, industrialists, statesmen—are asking themselves if engineering students are sufficiently visionary and possess the inherent capacity to handle the full range of their future responsibilities.

It would not be my wish to attempt to give you inexorable rules to follow in preparing for and practicing your profession. You, alone, must decide what you wish to accomplish in life as a student, in your professional career, and as a citizen. Perhaps, however, it might be well at this time, to relate some of the factors which appear to be or are instrumental in constructively shaping the types of engineers one would like to feel were launched into a future with a prospect toward a better world-to-be.

*Lincoln Lecture, The Ohio State University, February 21, 1946.

Engineering Preparation

It would be an involved study in itself to analyze curricula and make specific recommendations. There are some generalizations, however, which it is well to keep in mind in one's preparation for an engineering career.

You have, no doubt, read of the various reports which educational institutions such as Harvard, Yale, and Princeton are releasing. The tendency appears to be to place emphasis on increased independent study, on outside reading, and on avoidance of over-specialization. There is a plea to discourage premature concentration which results in a specialist who has failed to build upon a broad foundation in science; is incapable of regarding his specialization in broad perspective; and who completely disregards the effect of his specialization on other fields. The war has been vastly instrumental in emphasizing further the importance of broad types of training in contrast to narrow concentration.

What is especially desirable is that one should have an adequate education in engineering fundamentals, that he be well-grounded in basic principles. If he is, there will not be the danger of over-specialization with its attendant inability to see the part in its relationship to the whole. We often content

ourselves with the thought that it is impossible to remember everything. Admittedly, it is an important function of your training to teach you where to go for information. But it would be a grievous error to take this as an excuse for not becoming thoroughly well-grounded in basic concepts.

Perhaps if we were to consider education as an opportunity to achieve an attitude of mind rather than to gain a specific amount of information, our ability to handle the full range of our responsibilities would not be questioned by various groups. Actually, our knowledge is valuable only when it is used to the benefit of mankind. It is unfortunate that some have the attitude that well-paid positions are to be expected on the basis of examinations successfully passed, rather than on intelligent use of acquired knowledge. With a firm grasp of fundamentals as a basis, the engineer should inevitably develop many valuable qualities in his professional experiences demanding initiative and intelligent application of his knowledge. In fact, eventually these very qualities may be of far greater importance in his life actually than the technical knowledge which formed so valuable a base.

The complete grasp of fundamentals and the development of the habit of seeing one's particular interest in relationship to the whole will be aided and abetted by your professors. It is a truism that where great men are found, behind them will most often be represented the work and influence of great teachers. But there will be a part of your education even during your years of life at college which must derive from your own initiative and effort. There is so much to teach in so short a time, that in certain phases of your education, your teachers can do little more than indicate and stimulate your desire to learn beyond formal requirements. As engineers, you will find that what you achieve will have its effect to a degree on economics, politics, society in general. One way in which you may become appreciative of these social ends is through your "outside" reading. It is said that no man is really civilized or mentally adult until he comes to the realization that the past, present, and future are indivisible. Your reading will expose current problems in need of engineering technique; and you, of course, realize that understanding cannot be taught. You, yourself, have to acquire this element, known as understanding, through your contact and experience with people, books, and work —more or less a matter of conscious exposure and effort.

It can be noted more than ever before, that business enterprises are publishing histories of their development; and in the best of these, the social and economic backgrounds are given with great detail and care. Take, for only one of many examples, an excerpt from a publication recently released by a nationally prominent manufacturing company:

> Perhaps the Civil War and the Reconstruction period following it delayed the arrival of the Industrial Age. It is more likely, however, that the world was not ready for the Industrial Age until 1880. Many other things had to happen before an industrial economy could be established. . . . And of course mechanical superiority alone could not create an industrial economy. Social, economic and political conditions must be favorable before industry can thrive in a large way.

And so, in this manner, throughout the publication, the manufacturer has carefully traced the background of his

expanding business up to the present. The value of this approach is well expressed by Macaulay: "Those who compare the age in which their lot has fallen with a golden age which exists only in imagination may talk of degeneracy and decay: but no man who is correctly informed as to the past, will be disposed to take a morose or desponding view of the present."

Thus, in an invention or discovery there are the factors of a social and traditional background to be studied, and do not think that there is much to the oft purported "accidental discovery." If the facts be known, it will usually be found that suggestion and inspiration come only after the person responsible for the innovation has long struggled with the problem, often with the "subconscious" working overtime. Furthermore, the suggestion comes most often to the individual with the exceptionally well-prepared mind. Here, again, is the idea of a firm grasp of fundamentals, together with an understanding of the past in order to recognize the significance of the present, and the possibility of the future.

Admittedly, if it is to history that one goes to study trends and relationships, he will find quite frequently the academic historian has failed to comprehend latent technical causes. The technician might give a truer interpretation. It could well be our challenge in analyzing events to determine the interrelationship between technical invention and human progress.

There is the criticism that engineering education does not encourage the idea of the unlimited horizon; that there is a tendency to restrict teaching to fixed scientific knowledge having immediate applications. It is true that there is a growing realization of the need for more emphasis on the social and economic phases of engineering training. This is being stressed to a greater degree, as is evidenced by the lengthening of engineering curricula to five years by several leading universities. Even a casual review of that splendid report of the Harvard Committee, "General Education in a Free Society," is evidence that great minds appreciate the inadequacies and are attempting to analyze and rectify them.

In the meantime, perhaps the student should assume some of the responsibility of compensating for any deficiency in liberal arts. He may take the initiative in reading and in gaining valuable experience during his summer work. The latter is a subject which would warrant detailed discussion such that time will not now permit. Suffice it to say, however, that all of the experience you can secure during your vacations will aid you in realizing the greatest gain from your formal education; will aid in focusing attention on any weaknesses in your training; and will assist in your later adjustment to life's practical needs after finishing school. To gain actual experience during your formal education affords purposefulness and reality to your studies, and will aid you in becoming not only theoretically but practically minded.

Engineering Practice

There are many variables which have a bearing on engineering decisions, only a few of which are: depletion of natural resources, growth of cities, decline of agriculture and employment, labor supply, and ever-expanding communications. In fact, the effect of all major social changes becomes reflected in engineering judgments; and it is necessary for the engineer to arrive at his decisions, in many instances, in the

light of the prevailing social doctrine. Acknowledging that there are many vocations in which the engineer plays a vital part, for our purpose, discussion will be purposely limited to industry in its broadest sense.

It is increasingly evident that the engineer must not be restricted to the purely technical, but must go further than production to distribution and proper utilization. There is a definite need for improved economics in the distribution phase of the industrial process. Here it is urgent that engineering techniques be applied, and it is a vast and fertile field for your investigation. A recent study of distribution forcefully emphasized that the service of many thousands of engineers will be required in this field. It is not my wish to give the latter undue emphasis; except to state that it is indicative of the broadening scope of engineering—only one of many possibilities to which engineering techniques will be increasingly applied. And it is to the graduate that industrialists look for most of the original and vital ideas which lend a dynamic and healthy influence to forge a pattern of future betterment.

In the past it has been the engineer's policy, by and large, to leave the ends to other groups, while he concentrated on the means. With his training in science, which enables the engineer to approach his work with imagination, view it with objectivity, always with respect for exact truth, he is in an excellent position to see that the material things and processes he manipulates have value in contributing to the social and economic structure. If he exploits new means of power and production without regard to waste, unfortunate repercussions will be felt in the years which follow. Recent events have made it only too evident that we are increasingly dependent on the application of science, and this gives to the engineer an important position in preserving the best in our mode of life.

By these comments I wish to emphasize the desirability of raising the engineering profession to the highest possible level. If the engineer analyzes his work in industry in the light of its ultimate value, we should probably arrive sooner in gaining this new level for our profession. Then there is an even more personal code of ethics to follow which would add to the prestige of our profession. The statement has been made that the chief obstacles to the success of the engineer are of a personal and administrative rather than a technical nature. Through the years we have recognized that there are certain practices which make for harmonious relationships, respect, trust, and cooperation. Briefly, it might be interesting to note some traits of a person with whom it would be a satisfying experience to be associated.

He is able to delegate work intelligently, thus not only developing the abilities of his employees, but also avoiding the fallacy of trying to handle too much himself. This makes not only for well-developed and able assistants and potential leaders, but a strong organization as well. In making decisions he first gathers the essential facts, and realizes that there are times when a mistake is not so serious as failure to take a definite stand. He carries out even minor duties to the best of his ability, important in cultivating good work habits, and often an ultimate factor in his promotion. Negligence or indifference in routine details makes a poor showing and does not inspire confidence in one's ability or attitude.

He does not ignore his superior, al-

ways remembering his superior is the man to whom he is directly responsible. Associating with someone who is considered unworthy of personal loyalty makes for an unpleasant and non-productive situation and indicates why the choice of the right employer is of primary importance. At the same time, as long as one is working for another, he has no choice but to recognize his superior's authority and to carry out his orders.

There are an unlimited number of desirable personal characteristics, some which we fail to recognize, others which are obvious, yet whose value we underestimate, such as ability to express oral and written thoughts clearly; personal appearance; consideration and understanding of others; and the genuine desire to cooperate. One of the most constructive, practical, and interesting references which could be recommended is a paper by W. J. King of General Electric. It is entitled "The Unwritten Laws of Engineering," which Mr. King states are for young men just starting their careers and for older men who perfectly well know the thoughts suggested but who all too often fail to apply them in practice.

Civic Responsibilities

As a group of engineers, we have been charged that as a result of the narrowness of our scientific training, we emerge from college with little knowledge or interest in outside affairs. If the truth were known, we could possibly make the counter-charge that our ignorance of non-scientific matters is not nearly so appalling as the art graduate's ignorance of science. Yet such a charge would be purposeless. Then, too, in all probability, the war has been instrumental in increasing the art graduate's appreciation of the role of science.

What should give us pause for serious thought is that various groups such as economists, for instance, have been solely responsible for our administration at a time when the very basis of social activity has been profoundly altered by scientific progress. Take, for example, a report on the recent United Nations Conference at San Francisco. Nearly half a hundred organizations were represented to serve our Government, among which were labor, agriculture, business, religion, education, et cetera. But what of the engineering and scientific groups? Conspicuous by their absence! We read that a wide range of professions had individual consultants numbering over four hundred there to give their aid, but was an engineer or a scientist present? Regrettably the answer is "no."

Could it be that we are considered so far from the world and worries of men as to make us apathetic in our services to the public? It is incumbent on you students to become closely associated with and actively interested in the public life of your community and nation so that you can realize that very old definition of the engineering profession as "The art of organizing and directing men, and of controlling the forces and materials of nature, for the benefit of the human race."

True, you cannot use your slide rule to arrive at the exact answers, but that does not relieve you of the duty to exercise your judgment in the uncertain affairs of man. Surveys in engineering societies have revealed that a negligible number of engineers are associated with social agencies. A reluctance to be of constructive help on community issues makes for an unhealthy political

situation. The community is a single unit in our political hierarchy, and to maintain a hands-off policy and at the same time condemn local or national political machinery will never promote the best in our system of government. If each engineer gave a single public official the benefit of his acquaintance, it would be a step in furthering engineering for the good of man.

Nor should the engineer's efforts be confined to the purely local. Take, for instance, our relationships with other countries. Our present generation has recognized, more than any other, the significance of power in domestic and international relations. Force is a necessity in any system; but we must never fall into the opposite error of supposing that force is everything, nor should this fact ever be forgotten. The practical and the ideal, naked power and moral values, are alike constants in human affairs. Neither force nor idealism, alone, can ever be enough; any successful human institution must take account of both since both are ingrained in human action. To say this, however, solves no problems; the true issue lies in the fusing of these elements. No one can offer a final answer to that issue, but the great service that well-informed and earnest citizens can render is in that of exploring these thorny fields and providing the tools of thought and emotion with which workable answers may ultimately be developed.

Perhaps as engineers we have leaned too far on evidence and logic as guidance and made certainties and laws our guide. There is such a thing as insight and intuition which the social scientist must employ, and it seems that there must be a point of contact between him and the physical scientist.

There is no more ordered security for the engineer than there is for anyone else. Right now he is enmeshed in the universal struggle between free enterprise and collective security. He must realize the import of the choice between lessened initiative and individual freedom in exchange for a so-called promised security. Many of us cannot be convinced of other than the fact that in order to secure wealth, it must be produced; that thrift and investment are indispensible; that purchasing power does not spring full-bloomed. We cannot be convinced that democratic principles rightly exercised are not by far the most desirable, before we should wish unwittingly to relinquish them for principles which, as we observe the experiences of other countries, do not mean the good life.

Sometimes it is instructive to reflect upon the possibilities of the past, to imagine how different things might have been if circumstances had been different. Suppose our nation had had a law requiring that its President be chosen only from families of aristocratic wealth, so that no one could have voted for Abraham Lincoln. Suppose the discoverers of radium, penicillin, and vitamins had been denied the opportunity to bring into being their talents to benefit mankind. We shall never know, regardless of all our blessings and our favored position in the world, what we have lost because men and women who might have been of value to civilization were denied the opportunity to prove their worth.

If we truly want a better world, there is a way to secure it—start here and now to develop and make use of every good mind in our midst and never permit a single one to be crushed for lack of opportunity We do not know where a genius may turn up, and we cannot fail to avail ourselves of the

leadership of every genius in our midst. We have proved the value of democracy even though this is not a perfect country. We must apply our ideal of mutual respect and see that everyone is given a chance to prove his worth to society. This simply means that each must do his utmost and his day-by-day best, realizing beyond all else his personal and social responsibilities in our framework of self-government toward lasting improvement in our nation.

Three centuries ago, eight to ten generations as you choose to figure, our nation was practically an empty continent inhabited by a half million savages or barbarians. What has, in so short a time, made it in the opinion of the world the deciding factor of our times? It must, obviously, have been what was transpiring in our midst during this period, nothing more or less than the American way. And what was it except a challenge to brave, forward-looking people to build up and defend a great continent by themselves; to fend for themselves; to take their chances; and to keep their rewards—large chances, large profits, but somehow, an advance for all. Compare such reasoning about voluntary cooperation of highly competitive industrial concerns for the sake of winning the war with what one would expect from a leveled-off routine performance geared to a least efficient index.

Our geographical frontier may have been effectively declared closed with the entrance of the twentieth century, but our technological frontier was just emerging at that time; and see where chemistry alone has taken us to the present time! Cellulose is becoming ever more and more important in many of our fundamental products for clothing; and the deep south may turn into a vast region of carefully tended forests instead of plants for cotton bolls. Imagine the economic, social, and other changes involved. We should do well to consider such aspects of our ever-changing picture in the days to come. Any thought of our having achieved a finished economy is simply groundless, even as any prediction of actual technological unemployment is a pure prejudice. Think of the number of jobs, when you hear about "technological unemployment," which have been created by new inventions and materials. In practically every case, the new things which have not only made new jobs but have added to the comfort or enjoyment of every citizen who receives the work and the pay. In our nation, we had land and opportunity, and have developed a new conception of what life may be, and what enterprise and cooperation can be made to serve—not just mere luxuries for the few but more of the blessings of life for all.

Enumerate the variety of new goods and jobs produced since the beginning of the twentieth century, and ask yourself seriously how many of them we should have if it were not for the incentive of the profit motive on the part of countless individuals; or if, on the other hand, we had all just folded up and demanded our Government to make some sort of life for us. Picture all the experiments, the failures, the losses, the gambling chances taken to make one lucky find! No government agency can be expected to evolve progress in this way since the wish is not paid for except negatively, and that is what kills initiative in bureaucracy.

It will not be necessary to maintain private enterprise but to permit such enterprise to earn and retain enough profit to enable it to make the experiments and take the risks of loss from

them. We cannot go on to more goods and more jobs without research; but research is slow, risky, and costly. Money for it can come from only one of two sources, private savings—corporate or individual—or from the government via the taxpayer.

My wish is to impress you with the thought that we engineers are responsible for making our world different. We have a responsibility in guiding this change. It is only elemental to realize that these changes will be worthwhile if they improve life for human beings.

Engineering Opportunities

Now that the war is over, engineering predominates in all fields which will realize the greatest increased employment. In the liberated countries and in Latin America with its industrial development, alone, a need for ten thousand American engineers and technicians is predicted. And, incidentally, we are advised that the best way in which to win the good will of the people of Brazil is willingly to give them technical help. Because of America's industrial prowess, the youth of South America is increasingly interested in the United States for their engineering education. There was a time when they turned to Europe for this type of training.

We know that progress is inevitable in our country; and similarly, we know that both technical and scientific development are dependent on the engineer. He will find his work can be stimulating and creative; that it calls for a wide range of abilities; and that opportunities for advancement are encouraging, e.g., as consultants, executives, and functional division heads. Further, it is constantly pointed out that young men who are qualified engineers are going into other fields. One reason for this is that the graduate of an engineering school finds he is excellently equipped for other vocations.

A brief glance will show there are many promising and important fields—all of which, of course, could not be covered at this time. There is a predicted industrial, commercial, and residential expansion in air-conditioning. In the chemical field the outlook is good, with synthetics offering opportunities, in food-processing, et cetera. In the electrical field, communications suggest an exciting future. Four years ago electronics was a billion dollar industry; and in the following year, the figures soared to four billion, greater even than the prewar automobile industry. The newness of this field insures expansion, with new equipment needed; new applications; new manufacturing machinery. It will be upon your training, upon your ability to promote new ideas and to organize the work to be undertaken, that advancement will depend. You will be a vital part of the nucleus around which large industries will be built. This applies not only to the electrical field, but to the other branches of the engineering profession, as well.

Professional Obligations

Upon the status achieved by the individual engineer will depend the cumulative effectiveness of his profession. If we are often remiss in seeing beyond the immediate application of our engineering education, the schools alone cannot be blamed for this. Perhaps the engineering profession has not in the past been fully cognizant of the encouragement it could give to young graduates to continue their learning after formal education ceases.

The Engineers' Council for Profes

sional Development, an advisory service organization acting in accordance with its constituent bodies, has concerned itself with the period following the student's graduation. I believe that this is good and significant, for it should be a strong factor as should all engineering societies, in promoting coordination, inspiration, and social awareness at a time when the engineer is technically well-equipped and approaching maturity, a period when he should be appreciative both of social and technical forces.

Previously mentioned was the fact that a great percentage of graduates do not work in fields for which they specialized at school. Often this is not a matter of choice. Through activity on the part of societies, waste of engineering material could be drastically reduced by better placements and opportunities.

What engineers have to do and how they should be prepared to handle their responsibilities must be continuously considered and defined. Herein lies one of the greatest contributions of our engineering societies, dealing as they do with the broad problem of professional development. Through an expression of the principles of the engineering profession, an indoctrination of its standards is effected; and furthermore, not only is the individual engineer benefited, but public recognition and confidence in the profession are established.

Membership in national engineering societies should aid the young engineer in developing self-confidence; in expressing abilities of an organizational nature; in providing informal association with senior members; in encouraging further study and greater achievements; in keeping abreast of engineering developments and in becoming a vital part of these developments. On the other hand, your enthusiasm, varied points of view, and fresh outlook should be of inestimable value to your profession, recognition of which is made possible not only by the endeavors of individuals, but their collective effort as well.

There is so much one would like to say to the young engineer—now especially when his best efforts are needed in a troubled world. Perhaps one could do no better in closing than to quote "The Faith of the Engineer," formulated by the Engineers' Council for Professional Development:

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forbears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles

of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially, to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

Should Engineers Study Statistics?*

By HOLBROOK WORKING

Professor of Prices and Statistics and Chairman of Committee on Instruction in Statistics, Stanford University

The title of this paper is a purely rhetorical question which may be answered at once and briefly: engineers must study statistics. The purpose of the question is to lead to two others: *What* engineers should study statistics? and *what facilities* should engineering schools provide for such study?

These questions cannot be answered either easily or briefly, nor am I personally able to give a complete or final answer to either of them. They must be answered by engineers themselves, such engineers as my friend and colleague E. L. Grant, who know statistics as well as engineering. I am not an engineer, though I have some qualifications for speaking somewhat tentatively to these questions.

Although the use of statistical methods in industry increased by leaps and bounds during the war, there are still relatively few engineers either in industry or in our foremost educational institutions who know what statistics is who are even fully conscious that the word statistics has an important meaning in the singular sense. In the plural it means figures, but in the singular, a branch of mathematics. My first major task here is to try to make clear what statistics is, and my second, to indicate how engineers are using statistical methods. Information such as I shall present affords the basis on which you must endeavor in your own institutions to find solutions to the problem of helping engineers to learn the statistics that they now must learn.

Two Warnings

Before I turn to these major tasks, allow me to post two warning notices. First, there are many men who are deservedly classed as professional statisticians in your own institutions who can give you little help with this problem because they are too ignorant of the uses of statistics in industry; and there are not a few such professional statisticians who will be unable to help because they do not themselves know enough of the kind of statistics that engineers need to know. Much of the statistics that an engineer most requires is beyond the necessary knowledge of many competent economic statisticians, for example; and a good bit of it has been discovered so recently that routine teachers of statistics have not mastered it. In our wartime courses in statistical quality control, we encountered the difficulty that a number of our instructors—people who ranked among the respected professional statisticians of the country—protested at the crudity of the statistical control chart method which employs

* Paper presented at the meeting of Pacific Southwest Section, S.P.E.E., Berkeley, California, February 23, 1946.

the range as a measure of dispersion. The range is simply the difference between the smallest and the largest of a set of measurements. It has always been viewed intuitively as the simplest and most obvious measure of dispersion, but until recently it has been regarded as useless for precise quantitative work. These statisticians did not know that fundamental research in mathematical statistics some years ago established the range as a reliable and highly useful measure of dispersion. The research is too recent for its results to have got into more than a handful of the statistical texts and manuals.

I caution you, therefore, to look well to the qualifications of any statistician whom you consult on the engineering uses of statistics.

My second warning is that you must discard the prevalent notion that statistics is a subject of principal interest to the industrial engineer. There is indeed a category of statistical knowledge and skills which is of concern primarily to the industrial engineer, but the engineering applications whose development has led to my position on this program concern other classes of engineers more directly and intimately than they do industrial engineers. It is still not clear in my mind how much these new developments are likely to change the needs for the training of industrial engineers. It is quite certain, however, that they require careful reconsideration of the educational requirements for mechanical engineers; and probably also for electrical, chemical, and metallurgical engineers. With regard to civil engineers, I am less certain. Some jobs that fall naturally to civil engineers require for their efficient handling a good knowledge of statistical theory, but I do not know enough of civil engineering to judge whether such needs are rare or frequent.

What is Statistics?

Early in the war, at the beginning of Stanford University's experiment in conducting short intensive courses in statistical quality control for war industry, Col. O. C. Seagrave, then in charge of inspection for the San Francisco Ordnance District of the Army, told us that we made a mistake in using the term "statistical." There was much point to his remark. The word statistics brings to the minds of most people quantities of figures, whereas we were concerned with statistics as a means of getting more information out of fewer figures.

Engineers are familiar with a similar problem. When you speak to the layman about mechanics, he thinks at once of people who work on automobiles, or who pretend to work on them. Such misunderstanding presents a difficult problem if you have to talk much to laymen about the principles of mechanics, and you know that it cannot be solved merely by finding another word to carry your meaning. The real difficulty is that the layman does not possess many of the concepts and ideas associated with the subject. He must become acquainted with those concepts and ideas before you can discuss them intelligibly with him.

So it is with statistics. You cannot understand a discussion of statistics until you know what statistics is, and you cannot learn much about statistics in half an hour. For the ordinary engineer to acquire understanding of statistical discussion takes many hours of attentive study and thought, just as it would take me many hours to learn to discuss mechanics intelligently.

One feature of statistics that needs to be emphasized at the outset is its character as a subject which deals with concepts and ideas, some of the most important of which are relatively new and are still largely unfamiliar to people whose scientific and technical training is otherwise excellent. They are of course dealt with mathematically, but for anyone who is not making active technical use of statistics, the important aspects of the subject are the concepts and ideas and not the mathematical apparatus for handling and applying them. It is impossible for me to present the essence of the subject in a part of one short paper, but I shall try to give you a significant taste of the subject, if only a small one.

One basic concept of statistics is that of the frequency distribution. I shall assume that all of you have met and mastered that concept, though I know from wide experience that it is unfamiliar to most people in industry, who have much need for it. Perhaps you may recall that you had some difficulty in grasping the concept of the frequency distribution when first introduced to it. The circumstances of my introduction were such that I remember vividly my difficulties of comprehension. After a period of mental struggle, I got the idea clear, and then I was puzzled and chagrined that what finally appeared so simple an idea had caused me so much trouble.

What, then, does the statistician do with this concept? The principal statistical use of frequency distributions—(I am speaking now of the brand of statistics that is of widest concern to engineers) is in connection with another statistical concept: that associated with the problem of evaluating the confidence to be placed in calculations from numerical data. This concept in its simpler forms is familiar also to most engineers, I believe. You deal with it in terms of probable error. Incidentally it should be remarked that statisticians long ago stopped talking about probable errors. There is nothing particularly wrong with them; they are simply outmoded, like the reciprocating marine engine.

I have talked with a distinguished engineer who held rather firmly that there is nothing much to statistics except the Gaussian frequency distribution and applications of it. One remark pertinent to such a view is that perhaps there is nothing to differential and integral calculus except applications of the idea of considering very small changes. Another appropriate response is that the Gaussian frequency distribution really occupies a rather unimportant place in modern applied statistics. That statement will shock some of my statistician friends, but I believe that there are few who will not agree on a little reflection. It was the great Poincare who wrote fifty years ago,* quoting M. Lipmann: "Everybody believes in the law of errors, the experimenters because they believe it is a mathematical theorem, the mathematicians because they think it is an experimental fact." That statement carries wider implications today than were originally intended.

The Gaussian distribution occupies indeed the position of highest honor in statistics, but a position in some respects like that of a venerable emeritus professor who long since ceased to do much work. He is honored for what he has done; his example is an inspiration to all; and his works are studied as a background for more recent investigations; but if you want a job

* In *Calcul des Probabilités.*

done, you go to one of the younger professors. Many an active and highly competent practicing statistician will work for years without ever using the Gaussian distribution. If all the tables of that distribution were lost, he would not miss them. He may use the time-honored companions of the Gaussian distribution, the binominal and the Poisson, which have, so to speak, renewed their youth and vigor; he uses most often the "alphabetical" distributions—the distribution of t, the distribution of F, the distribution of z, and the distribution of X^2;—and he may have much use for that newcomer, the distribution of the range.

It should especially interest this audience that the first and perhaps still the most important of this company of relatively new frequency distributions was discovered and published forty years ago by the statistician of a brewing company. The use of statistics in industry is not an innovation of yesterday; what is new is the discovery of the very wide scope of applicability of statistics in industry. That scope is itself largely the result of statistical discoveries and inventions of the last twenty years or so.

Engineering Uses of Statistics

I have spoken as long as I may of what statistics is, and of course you do not have a much clearer idea than you sat down with. It will satisfy me well if you have gathered only that to learn what statistics is requires some serious study, and might be worth it. I turn now to the question of engineering uses of statistics.

When an engineer speaks of engineering uses of electronics, he speaks commonly, I suppose, of uses of electronic devices; but he knows that primary importance attaches to the knowledge rather than to the devices that embody it. So, at least, it is with statistics.

We may well consider first statistics in research. If research involves only one independent variable, and if the results need not be very precise, or if data can be had in abundance at little cost, the research has no need for statistics. If, however, the experimenter cannot control all but one variable, or if data are expensive, he will do well to consider bringing statistics to his aid. Statistical analysis will sometimes reveal facts that would have been missed without it, and it is essential if the experimenter wants confidence that the data are adequate to support conclusions without piling up a clearly superfluous volume of data. Drawing conclusions without statistical tests is like building a suspension bridge without knowledge of the tensile strength of the cables. A perfectly safe bridge can be built without such knowledge, but it will be unnecessarily expensive.

Perhaps the most important use of statistics in experimental research is one that is commonly discovered too late. The experimenter collects his data, tabulates them neatly, calculates averages and draws charts. After sweating over the results for a few weeks or months, he takes them to a statistician for help. If he has been so fortunate as to find a sympathetic and really competent statistician, the two work together for a while; they come out perhaps with a conclusion or two that the experimenter had missed; the statistician confirms the experimenter's fears that most of his data really do not prove anything; and then the statistician gently breaks the news that the experiment was not planned properly. The experimenter should take this news with due humility, but instead he

will probably ask the statistician what he knows about airfoils and wind tunnels.

It may be that the statistician had never heard of a wind tunnel before he was brought this problem, but if he is competent, he now knows some things about this sort of a wind-tunnel experiment that no aeronautical engineer who is not also a good statistician, could have learned by himself. One of the most important and most difficult branches of modern statistics goes under the title "The Design of Experiments." Its motto might well be: "If you have a large and complicated experiment to conduct, call the doctor before you need the undertaker." Every competent statistical consultant far too often has the unpleasant and usually ungrateful task of telling the experimenter that his data, assembled with so much labor and scientific devotion, are fit only for a quiet burial.

After scientific and engineering knowledge has been obtained, it is used in design. Here again statistics is needed. It is not enough for the design engineer to know the average strength of aluminum spot welds; he should know also their variability; and he should know the extent to which the usual variability of spot-weld strength can be reduced and the average strength increased through simple statistical control of the welding operation.

Usually after the design engineer has finished his job, someone else assigns the tolerances for dimensions. Sir Charles Galton Darwin, Director of the National Physical Laboratory in Great Britain, made a pointed remark on the subject of tolerances a few years ago. Too often, he suggested, tolerances look as though their setting had been assigned to a junior assistant draftsman who, "anxious not to get himself into trouble, would, as a general rule, think of the smallest number he knew and then halve it." * Quality of products will be improved, many production headaches eliminated, and costs reduced, when tolerances are properly based on statistical information regarding economical limits of variation under good production practice and regarding true functional requirements.

When design specifications have been fixed, they will usually be found quite inappropriate for inspection purposes. It is one thing to write specifications that state clearly and simply what the design engineer wants and needs; it is quite another thing to write specifications by which the inspector can economically and reliably assure that requirements are met. Whenever any large volume of inspection is required, it is likely to pay well to have the specifications completely rewritten from the standpoint of practical inspection requirements. Anyone who wants to pursue this topic further should study carefully the new specifications being issued by the Bureau of Ships of the U. S. Navy. All Bureau of Ships specifications are being reviewed, and as rapidly as possible are being revised to utilize modern statistical principles.

Research, design and specifications, all requiring statistics, lead to production. It is in conjunction with production, including assembly and packaging and the associated inspection operations, that use of statistics in industry is just now expanding sensationally. These uses, going generally under the name of statistical quality control, are doubtless being over-sold here and there. Broadly, however, and neglecting special cases influenced by mis-

* "Statistical Control of Production," *Nature*, May 23, 1942, p. 573.

taken ideas or bad judgment, statistical quality control is only just beginning to come into its own. Less may be written and said about it in the future than in the recent past. It is a bright new idea now, which later may be almost as prevalent, yet as little noticed, as electric lighting.

So much has been said and written elsewhere on statistical quality control* that we may pass that use of statistics with only two further remarks. The first is that mistaken ideas of statistical quality control are still prevalent, based on knowledge as it existed ten or twenty years ago. Today nearly anyone will have to make several guesses before he strikes a type of production establishment in which statistical quality control has not found a useful place. The second remark is one I want to put in the words of Fred Trowbridge, engineer in charge of inspection, testing and production control for Sentinel Radio Corporation. Trowbridge started using statistics seven or eight years ago with the idea that only one or two people around a plant needed to understand the methods. A year ago he wrote: "to achieve maximum benefits, it is essential that an appreciation of statistical philosophy be nurtured in the minds of production people and that these ideas be diffused as widely as possible among operating personnel." †

Finally, let me mention a quite different example. It was a professor of classics, if I am not misinformed, who led irrigation engineers to the use of statistical methods to improve their predictions of stream run-off from mountain watersheds.*

Instruction in Statistics

What are the revisions in engineering instruction that are required to catch up with the progress of the last fifty years in statistics? I have stated my incompetence to give a final answer to that question, but having devoted three very busy years to teaching statistics to engineers and helping them with their problems, I should be shirking duty if I did not venture an opinion.

There are four things which, in my judgment, are needed. First, engineering schools must establish evening courses and special intensive short courses for men already in industry, to help them remedy their present ignorance of statistics. Several prominent engineering schools have already made a start toward meeting this need, of which I have said a good deal in two recent articles already mentioned.†

Second, all engineering students should have a good course in statistics, occupying say three hours weekly for a quarter or a semester. It should be a course of quite different character from that now commonly given for industrial engineers. It should not aim at making statisticians of the students, which would be quite impossible in the time available, but should aim instead

* I have summarized some of the recent developments in an article in the December 1945 issue of the *Journal of the American Statistical Association* and a shorter paper in the January 1946 issue of the Journal of Engineering Education.

† "Statistical Quality Control in Radio Manufacture," *Quality Control Reports*, No. 5 (available from Production Research and Development Division, U. S. Dept. of Commerce).

* I refer to James Edward Church, of the University of Nevada, whose hobby won him international distinction as a meteorologist.

† See page 10 above. The *Statistical Journal* article contains much pertinent information omitted from the shorter paper in the Journal of the S.P.E.E.

merely at acquainting them with fundamental statistical concepts and putting them in a position to extend their knowledge of statistics when the need arises. It must include, of course, some instruction and practice in the use of statistical techniques, not primarily for the sake of the techniques themselves, but to give the students a chance to firmly grasp the concepts.

Third, some institutions at least must provide facilities for advanced instruction in engineering statistics. Most engineers need to know only the basic principles of statistics and perhaps a few statistical techniques especially suited to the problems they commonly meet, but every large industrial concern needs to have at least one person who is a reasonably competent statistician.

Finally, most engineering teachers need to revise some of their lectures. Problems to which the concepts of modern statistics are vitally pertinent are scattered all through the subject matter of engineering. Today these problems are treated usually with complete neglect of their important statistical aspects, or with a long outdated view of those aspects. It is not to be expected that the ordinary teacher of engineering should take account of yesterday's discoveries in statistics, or even of all the important and pertinent discoveries of the last ten or fifteen years. Few teachers of statistics do so well. But engineering instruction should not be fifty years out of date as regards the statistical aspects of its material.

The foregoing comments imply that the needs for change in engineering curricula and for revision of many courses is urgent. Emphasis on this urgency should be accompanied by a counsel of caution in making the changes. Good statisticians are scarce in relation to the demands for them today, and scarcer yet are people who knew enough statistics and who have also the temperament and point of view to advise wisely on engineering statistics, to teach statistics as it should be taught to engineers, and to consult effectively on the statistical problems of engineers.

And now, Mr. Chairman, I await with some fear and trembling the "chain reaction" that I have probably touched off.

NOTE ON STATISTICAL LITERATURE

Because statistical theory has been advancing so rapidly, there is no text in the field which can be recommended without qualification. A comprehensive list of publications on engineering statistics appears in "Bibliography on Statistical Quality Control," *Quality Control Reports* No. 11, 1945 (Production Research and Development Division, U. S. Dept. of Commerce), compiled and edited by Dorothy W. Goodfellow and Mason E. Wescott respectively. To the list of books included therein (pp. 46–48), may be added:

Tippett, L. H. C., *Statistics*, New York, Oxford Univ. Press, 1944. (A primarily non-mathematical book dealing with concepts and uses. The author is Statistician to the British Cotton Industry Research Association.)

Grant, E. L., *Statistical Quality Control*, New York, McGraw-Hill (in press).

Peach, Paul, *An Introduction to Industrial Statistics and Quality Control*, Raleigh, N. C., Edwards and Broughton, 1943 (out of print; revised edition in press).

Probably the most popular book among statisticians for their own personal use is Yule, G. U. and Kendall, M. G., *An Introduction to the Theory of Statistics*, London, Charles Griffin and Co., Twelfth edition, 1940. It is fairly mathematical in style though it does not presuppose acquaintance with differential calculus.

The principal American works written primarily for engineers are:

Freeman, H. A., *Industrial Statistics,* New York, John Wiley and Sons, 1942.

Fry, Thornton C., *Probability and Its Engineering Uses,* New York, D. Van Nostrand Company, 1928.

Grant, E. L.; Peach, Paul (cited above).

Shewhart, W. A., *Economic Control of Quality of Manufactured Product,* New York, D. Van Nostrand Company, 1931.

Simon, Leslie E., *An Engineer's Manual of Statistical Methods,* New York, John Wiley and Sons, 1941.

Anyone particularly interested in the Shewhart statistical control chart and its uses should consult also:

American Society for Testing Materials: "Manual on Presentation of Data," Supplement B, fifth printing, 1945.

American Standards Association, New York: "Guide for Quality Control and Control Chart Method of Analyzing Data," Z1.2, 1941.

American Standards Association, New York: "Control Chart Method of Controlling Quality During Production," Z1.3, 1942.

Creative Engineering Research: Its Stimulation and Development*

By W. R. WOOLRICH

Dean of Engineering, The University of Texas

The Mandates of Research to Industrial Progress

In highly competitive industries, especially those exploiting new and untrodden fields, the activity of competitors drives all existing companies to indulge in extensive research if they would survive. Paradoxically, probably many such companies will not survive even with their facilities for research, due to their inability ever to produce any one item or model for a long enough period to arrive at the profit-making or the so-called "break-even" point.

The losses, sustained by industrial adventures in effecting the introduction of a new type of machinery on the market of the United States, are sometimes staggering. In 1914, ninety-four companies displayed automobiles in the New York automobile show, yet at that time the national demand was relatively small. Fourteen years later only thirty-five companies were producing all of the automobiles of the United States. Only a small portion of those companies that existed in 1914 could be identified in these surviving thirty-five, yet our annual demand of automobiles had increased many fold. This is just a part of the story, for within these same fourteen years many other new companies had come into being, made their debut, then after a financial struggle closed their doors in distress.

This same story has been repeated again and again within the United States. You might tabulate the names of the manufacturers of tractors, of refrigerators, of washing machines, and of radios of the past quarter century, then review the list of those surviving in 1940. It presents an amazing picture of American sportsmanship in trying to play the manufacturing game with the statistical odds against ultimate survival of most of those who make the try.

Paradoxical as it may seem, America's readiness to destroy is responsible for much of her success in creative engineering and research. It is not uncommon to find manufacturing plants in the highly competitive fields in which a depreciation of 100 per cent in one year is considered sound business for all tools and special equipment. In such an atmosphere the man with inventive imagination certainly has an incentive to create the new.

American industry is replete with examples of machines becoming obsolete by technological advances so

*Paper given before S.P.E.E. Executive Council and Administrative Division officers meeting at Pittsburgh, Pennsylvania, on December 7, 1945.

quickly that the new replacement units were actually in the process of production before the original units had been completely installed. It takes courage to make a new investment which calls for the destruction of a very recent investment, but it is this readiness to destroy that gives life and zest to research and enables the American manufacturer to lead in most fields of production.

When an industry which involves a given class of equipment grows up, this destroying schedule is given some control. It is well known, for example, that the changes in the design of automobiles have reached the metered stage and the public is handed out a measured number of improvements each year under the well-sounding title of new models. Those who are best acquainted with the automobile industry can attest to the practice of keeping at least three seasons ahead of the production line in approving future designs and models.

Youth and Creativeness

Youth has more courage to attempt seemingly impossible things than is characteristic of older men. When and how are these young men to be found?

As has been repeatedly pointed out by others, a survey of the great inventions of the United States reveals that a large number of the basic inventions are from the creative works of very young men. Westinghouse invented the air brake when only twenty-one years of age; McCormick was twenty-two when he patented the harvester; and Howe contributed the sewing machine at the age of twenty-seven.

Those who have indulged in inventive work know that many years of experimenting preceded the actual patenting of a device. These men mentioned above were, then, well within high school or college age when they undertook their experimental work.

Unfortunately, in many of our scientific and engineering colleges of this land too many of the faculty men who could inspire creative research and design confine their teaching to the senior and graduate years. Probably the "hunting" would be more fruitful if it were projected back even to mere freshmen or to high school students.

Some of our large manufacturing companies have recognized this creative urge of youth and are successfully promoting searches over the United States for young men of genius in the high schools. The writer predicts that much more of this type of searching will be done in future years.

A very general trend of the high-school administrators has been to eliminate such science courses as physics, chemistry, and physiology and to reduce the mathematics courses to a critical minimum. This backward movement needs the thoughtful attention of every scientist, engineer, and lay citizen of this continent.

Invention and the "Flash of Genius"

In the legal arguments in Washington relative to the rights of inventors there has been much said about the "flash of genius." An invention or discovery has been portrayed as an idea that suddenly comes down out of the ethereal to the mind of the searcher; and without much effort on his part it becomes his discovery and, if patented, his property.

Where do these ideas come from?

The process of discovery is long and arduous. It combines intelligence and intuitiveness well coordinated into a search in the unknown. This "flash

of genius" is the reward that comes to those who have first the germ of an idea—then, as this grows in proportions, there develops a horoscopic searching and visualization into the future. At first this parade of confusing ideas is most kaleidoscopic and ill defined. But as the searcher gazes further into this future, there eventually emerges a clearly defined solution —a reward for complete saturation in what has gone before and a consecration to the task of seeking avidly into the future.

Such an intuitive conception is born only of long hours of intelligent searching and, while the rewarding moments may be poetically defined as a "flash of genius," Edison was most correct in emphasizing, "The only genius is hard work."

The Creative Immigrant

During the past six years much criticism has been made of the refugee scientists within the United States who have acquired national acclaim for their contributions to our scientific literature and have received popular recognition afforded them by a public that has been enchanted by their salesmanship and by their optimistic enthusiasm.

There is no question but that the romance-loving public has been most susceptible to the over-selling on the part of a goodly number of European and Asiatic refugees, especially in fields where abilities could not be readily measured. There are, however, many hundreds of these refugees who are of a very high type of personality. These men have taken their places with due humility beside our American engineers and scientists and are making a great contribution to our American life. The United States owes much of its best invention to men of foreign birth. The modern European environment is not conducive to invention except as it relates to war and defense. The European economic structure is such that its needs and wants in peace can be fulfilled by a continuation of the old. This represses research.

From the list of highly trained men who have during recent years found a haven for research from their European oppressors, America can expect a new upsurge of scientific invention during the years ahead. These refugees from Europe have been trained to work with great intensity and for long hours. Out of their consecration to the tasks they initiate for themselves we can expect them to produce significant results.

Fallacies of European Greatness in Research

In *Mechanical Engineering* for February, 1943, Dean A. A. Potter wrote, "Few realize that the Americans, to a greater degree than any other people in the world, are responsible for the most epoch-making inventions of the past century." *

A review of the great inventions of the world since the industrial revolution shows a preponderance of European inventors prevailed before 1840 but, during the past one hundred years, American inventors have pressed forward into the front position. As is indicated in the attached table of the U. S. Patent Office, more patents are granted annually in the United States than in any two other countries of the world and the United States grants a lower percentage of patents to foreigners than any other nation.

The migrations of recent years of eminent scientists from Europe, to-

* A. A. Potter, "The Pride of America," *Mechanical Engineering* Vol. 65 (1943), p. 133.

TABLE

PATENTS GRANTED BY VARIOUS COUNTRIES SHOWING PROPORTION GRANTED TO FOREIGNERS

(Figures by U. S. Patent Office)
(Conway Coe, Commissioner)

	Annual No. of Patents Granted	Number Granted to Foreigners	Percentage Granted to Foreigners
United States	48,697	6,421	13.2
Germany	20,621	5,327	25.8
France	20,025	9,994	49.9
Great Britain (1930–5)	18,417	9,522	51.7
Italy	10,634	6,782	63.8
Canada	9,269	8,368	90.3
Belgium	7,315		
Switzerland (1930–6)	7,307	4,066	55.6
Japan (1930–6)	4,845	1,165	24.0
Austria	4,475		
Czechoslovakia	3,613	2,749	76.1
Sweden	2,840		
Holland (1930–5)	2,674	2,164	80.9
Australia	2,460		
Hungary	2,334		
Poland	1,845		
Denmark	1,590	1,056	66.4
Norway	1,428	1,031	72.2
Roumania	1,078		

Numbers are averages for eight years 1930–37 unless otherwise indicated.

gether with the great incentives to native-born engineers and scientists for new invention in both productive and destructive equipment, should give the United States a new advanced position of leadership, never before realized. Further, this great pool of creative technologists should do much in solving many of our post-war employment problems.

CREATIVE RESEARCH IN OUR EDUCATIONAL SYSTEM

A fundamental activity of scientific and engineering education is given by some authorities of engineering education as "the fostering of research as a function collateral to teaching." If it is accepted that research should have, primarily, an educational objective with the material results only incidental to the educational process, then research within educational institutions will not become competitive within the institution with the educational function. There are some examples in American universities and colleges, however, where the commercial research objective has seriously disrupted the teaching personnel.

Creative research in the educational institution should be approached from a broad viewpoint. For example, a complete industrial analysis of the economic possibilities of a proposed plant for processing available kaolins might incite more creative inspiration and courageous industrial frontiering than the invention of a new type of radio transmitter. The development of a new small industry is a creative enterprise of a very real type and may call for much more ingenuity than the invention of some new instrument of equipment.

Probably the greatest mistake made in university and college research is the failure to lead the way in following through to the point of useful application of creative invention. Mr. Charles Kettering realistically refers to the three stages of creative invention as (1) the idea stage, (2) the "shirt losing" stage, and (3) the profit-making or mass production stage. It is very necessary to provide the leadership and inspiration to guide the student through this "shirt losing" stage, if he is to develop that confidence necessary to become productively creative in his years ahead.

In every university scientific or engineering laboratory that has been established for a decade or more there

are too many projects that have been discontinued because of the lack of inspirational leadership from the directing personnel through the second stage. Federal and industrial laboratories are likewise not without their own sins of omission in this failure to follow through promising research. The writer found one of the most fruitful sources of possible new enterprises was the dormant discoveries—already through the laboratory stage—permitted to rest peacefully in some department archive in Washington.

Tracking in Creative Research

An argument can always be started with contemporary scientists and engineers whether a research department can reproduce itself. There are many examples of research departments in both colleges and in industries ascending to notable heights and then becoming disappointingly decadent with the passing of the original leaders. This deterioration is particularly noticeable where the leadership has been highly individualistic, especially in fields of rapid change.

Creative research is not imitative. It requires inspiration and a minimum of dictation. When a research department cannot reproduce itself from generation to generation, the responsibility must be placed largely on the lack of inspirational leadership of the guiding director. Tracking and the encouragement of tracking are likely to be fatal.

Research departments can be made to reproduce themselves only through intelligent leadership, whether that leadership is available from the department itself or must be supplied by someone from outside of the department who is in a position to maintain an objective view of the job to be done.

Recognition of Creative Engineers and Scientists

In no one phase of American life has the United States been more neglectful than in her failure to recognize individual creativeness. Biographers, technical societies, and scientific academies have all been too prone to forget the frontier builders of scientific United States and pay homage to the political, military, and literary leaders of the nation.

A library search recently made by the author for a biographical sketch of one hundred men catalogued as giving the United States her greatest inventions revealed that many of them were absolutely "lost souls" in the library records; a second group, although listed in the principal encyclopedias and biographical libraries, had only incidental mention made of their principal invention, while a third group had been well recognized. There did not seem to be much relation to the space afforded them in their respective biographies and the relative importance of their inventions. It was evident that some few had had good biographical sponsors while others who had made as great, or perchance a greater, contribution remained unproclaimed on the printed page.

Probably this failure to memorialize these geniuses of the past is as serious a damper on creative invention as any one factor. Young men have raised the questions repeatedly, "Why are there so few scientists in the Hall of Fame at Washington, yet this nation is considered the haven of scientific inventors? Why do scientists on the Continent receive long written citations for their work while in the same fields our United States scientists are sometimes completely forgotten? Why

don't we, like England and the Continent, glorify our scientists by high national recognition?"

Some of these questions are not within our immediate power to answer, but the living scientists of each state should see to it that the illustrious sons and daughters who have contributed to science do receive biographical recognition at least equal to that of the contemporary contributors to politics, military advancement, and literature.

Can We Challenge the Men Who Have Created New Devices for War in the Immediate Years of Peace?

One of the most significant problems facing all of the creative scientists, and it is facing them right now, is, "How can they keep the curve of creative discovery and invention, that has been so greatly stimulated upward by the war, continuing on its upward climb?"

Many hundreds of these men who have made their contributions in the science fields during the war will experience great changes in environment and incentives as they swing into the procedures of more conservative peacetime life. Will they lose their enthusiasm for creating new designs and for making new discoveries when they return to peacetime existence?

No doubt these men will lose their enthusiasm for doing new and creative things if the leaders in their several professions do not do all within their power to inspire the very best in each one of these men and help to remove some of the hurdles from the successful prosecution of their creative work.

Specifically, those men who return to the class rooms, and especially those who are interested in graduate research, should be challenged with greater problems than they left behind in industry or in war laboratory. Are our faculties prepared to offer such challenging studies in our American universities?

Again there are those men who will return to industry from major activities at the front. Are we prepared to challenge them? Scores of these men have been on large enterprises where quick and creative decisions were essential procedures hourly. As many of these men take their places in quiet civilian life at greatly reduced salaries and responsibilities, what can be offered them to bring forth their best effort and zeal?

These questions might be multiplied many fold. If the scientific men of America would push forward under the stimulus of their work of the past four years, they must plan on keeping science and scientists ever progressively on the march. They must find ways of utilizing the brilliant and capable manpower that has made our defeat of Germany and Japan possible. The period of the past four decades, 1900–1940, will be completely overshadowed by the new inventions, discoveries and accomplishments of the period 1940–1980, if scientific and industrial leaders do their part in harnessing the creative genius of these men.

Can We Maintain New Frontiers in the United States?

There are those who seriously question whether the scientific men of North America can maintain the high leadership in creative invention when the nation grows old. Some predict we, too, will adopt the conservative attitude of those in Great Britain and Europe. If the United States will conserve her resources in soil, in minerals,

in fuel, in power and in humanity itself, then her growth in new endeavors is nearly boundless. If she permits herself to decay within, both scientifically and spiritually, then she too will go into senility and her creativeness will be less and less effective.

Summary

1. To lead in research, we must be ready to destroy the old to give a place to the new. Life cycles established by the Creator in which a place is given each generation by the passing of the aged of the generations spent is the pattern for progress in creative invention.

2. Greater emphasis should be placed in our educational system on developing ingenuity in our students. Too few graduates of our colleges are to be found in the catalog of great American inventors.

3. More effort should be expended discovering young men and women of creative ability. Experience indicates there is great virtue in developing this attribute at an early age.

4. Creative discovery must rely on intelligent activity and devoted study to bring forth those intuitive powers that are sometimes rewarded by new invention or the manifestation of "flash of genius."

5. It is a great incentive to many inventive minds if a definite and useful application is presented as a goal to be achieved. Discovery thrives most where new invention is given an opportunity for development.

6. During the past one hundred years the United States has surpassed any two of the other nations of the world in epoch-making inventions.

7. The research in any institution cultivating creative thinking should possess enough latitude to encourage new thinking. Too much tracking should be discouraged in research.

8. The scientists of every state of the United States should encourage biographical recognition of those who have made their contribution to their profession. The scientists of this nation have been remiss in this matter of recognition of contemporaries.

Engineering Student Enrollment Growing, But Far From Normal*

By WILLIAM B. PLANK

Head, Department of Mining and Metallurgical Engineering, Lafayette College

The grand total of 73,269 engineering students enrolled in the United States and Canadian schools as of November 5, 1945, and as shown on the following tables, will not greatly remedy the 150,000 deficit that is reported by Dr. Vannevar Bush, Director of the U. S. Office of Scientific Research and Development, to exist in the engineering and scientific manpower supply.

These figures were received in advance from the S.P.E.E. and are given in detail in the January, 1946, issue of the JOURNAL OF ENGINEERING EDUCATION.

Although the enrollment on November 5 has increased 76 per cent over the low of 41,632 in 1944–45, it is still 36 per cent below the peak enrollment in 1941–42 of 115,228. These figures include both undergraduate students and graduate students in the schools of the United States and Canada and are therefore comparable.

As was to be expected, almost half of this enrollment is in the first or freshman year and 25 per cent of the total are veterans. It is interesting to note also that 1,850 or about 2.5 per cent are women.

A measure of the seriousness of the engineering graduate supply in these two countries is indicated by the trend of the number of first degrees that have been conferred during this period of scarcity. These were as follows:

First Degrees Conferred

1942–43—14,714
1943–44—11,155
1944–45— 4,724

Apparently the bottom of the curve for the number of degrees conferred was reached last year because this year the total possible number of first degrees, as shown by an analysis of the S.P.E.E. figures, is 5,628. These include 4,971 seniors, 168 fifth-year students and 489 special students. It is reasonable to suppose that at least the total number of degrees to be conferred next June will approximate 5,000. Although this will be a slight increase over last year, it is still only about 30 per cent of the peak number of degrees conferred in 1942–43.

For engineering as a whole, therefore, the deficit in the normal supply of engineering graduates still exists. Undoubtedly, anything like a normal supply of engineering graduates will not occur until the present freshman class graduates in 1949.

* Paper read before Mineral Industry Education Division of A.I.M.E., Chicago, 2-24-46.

Since these figures were reported, many engineering schools have admitted additional students, principally veterans returning from the military services. Just what these numbers are is not known at present, but information that has been received from several different sources indicates that the present second semester engineering enrollment may be close to 100,000. As just stated, the bulk of this increase has come from the veteran ranks and has caused an overcrowding in many of the better known and larger engineering schools. The great danger here is that some institutions may be exceeding their proper capacity to handle this abnormally large enrollment, all in one class. The results of this crowding, being now principally in living quarters, will be much more acute in the departmental laboratories when these men reach their third and fourth years. In order to accommodate this large influx, undoubtedly, many institutions will have to institute speed-up programs and perhaps operate their laboratories and classrooms at night in addition to their daytime programs.

I am glad to report that the mineral engineering situation shows an encouraging increase in numbers in all of the four branches shown. The total of 3,079 students on November 5 is 140 per cent greater than the enrollment a year ago. This growth is almost double the 76 per cent increase in the total engineering enrollment during the same period. The mineral engineering enrollment, however, is less than ⅓ of the peak enrollment of 10,633 students in the United States and Canada in 1938–39.

With the acute shortage of men in mineral engineering, particularly in the mining and metallurgical industries, there is immediate and pressing need to increase the enrollments in these branches as rapidly as possible.

It might be expected that additional recruits to the second year will be obtained from the excessive enrollments in other engineering branches now in the schools. When the eventual overcrowding becomes apparent to these students, undoubtedly some of them will be influenced to choose a college course, such as one of those in the min-

TABLE I

ENGINEERING CIVILIAN STUDENTS AS OF NOV. 5, 1945, UNITED STATES AND CANADA 145 SCHOOLS

	Undergrads.	Graduate Students		Totals
		Masters	Doctors	
Mining	462	64	7	533
Metallurgy	820	361	33	1,214
Pet. and N. Gas	1,083	?	?	1,083
Ceramics	218	26	5	249
Geology	?	?	?	?
Fuel Technology	?	?	?	?
Special Stud's	?	?	?	?
Total Mineral Engineers	2,583	451	45	3,079
Chemical	6,915	727	124	7,766
Civil	6,891	315	27	7,233
Mechanical	13,099	423	31	13,553
Electrical	11,094	935	53	12,082
Others	28,564	899	93	29,556
Total All Engineers	69,146	3,750	373	73,269†*

* = Includes 5,941 students in Canada.

† = Resume:

Men	52,869
Women	1,855
Veterans	18,545
Total	73,269

From JOURNAL OF ENGINEERING EDUCATION, January, 1946, Advance Data.

eral engineering field where overcrowding certainly does not exist at the present time.

One of the most effective ways of meeting this situation is to increase the appeal to college students on the part of all of the agencies and industries connected with mineral engineering. A very fine example of this is the recently published pamphlet by the *Engineering and Mining Journal,* entitled, "Take a Look at Mining—Ex-Serviceman." This is the best example of vocational guidance literature of its kind I have seen. It deals only with the metallic and non-metallic mineral industries, however, but it is hoped that the fuels people, both coal and petroleum, will do something similar for their respective fields. The forthcoming pamphlets on geology and mining and metallurgical engineering, being prepared by the National Roster, are other excellent examples of vocational literature.

I feel also that the Institute's pamphlet "Careers in the Mineral Industries," so ably written by T. T. Read, should be revised and brought up to date in the light of things that have been learned during the war, particularly to include the role that minerals play in our post-war industrial developments, including atomic power.

For a longer range publication to reach the general public, I would recommend that Dr. Read's excellent treatise, "Our Mineral Civilization," written in 1933 for the Century of Progress Exposition held in Chicago, be revised and printed as a special publication of the Institute for distribution to the student associates and to the general public. "Minerals of Might" by W. O. Hotchkiss ought to be widely read.

TABLE II

ENGINEERING ENROLLMENT BY CLASSES, UNITED STATES AND CANADA, AS OF NOVEMBER 5, 1945

	Fresh.	Soph.	Jr.	Sr.	5th Yr. and Others	Total Undergrads.	Grad. Studs.	Grand Total
Mining	165	115	102	70	10	462	71	533
Metallurgy	212	159	172	127	150	820	394	1,214
Pet. and N. Gas	663	241	105	65	9	1,083	?	1,083
Ceramics	91	59	37	27	4	218	31	249
Total Mineral Engineers	1,131	574	416	289	173	2,583	496	3,079
Chemical	2,706	1,636	1,082	748	743	6,915	851	7,766
Civil	2,897	1,541	1,086	714	653	6,891	342	7,233
Mechanical	5,081	3,167	2,173	1,373	1,305	13,099	454	13,553
Electrical	4,987	2,617	1,566	949	975	11,094	988	12,082
Others	18,087	3,320	1,409	898	4,850	28,564	992	29,556
Total All Engineers	34,889	12,855	7,732	4,971	8,699	69,146	4,123	73,269

145 Schools.

From JOURNAL OF ENGINEERING EDUCATION, January, 1946, Advance Data.

TABLE III

ENGINEERING CIVILIAN STUDENT ENROLLMENT BY COURSES, UNDERGRADUATES AND GRADUATES, 1936–37 to 1945–46

	(1)	(1)	(1)	(2)	(3)	(4)
	1936–37	1938–39	1940–41	1941–42	1944–45	Nov. 5, 1945
Mining	1,652	1,892	1,978	1,501	224	533
Metallurgy	1,630	2,403	2,450	2,712	472	1,214
Pet. and N. Gas	2,466	3,538	2,877	2,143	376	1,083
Ceramics	738	825	843	746	190	249
Geology	567	844	792	?	?	?
Fuel Technology	66	24	44	?	?	?
Special Stud's	71	93	149	?	?	?
Total Mineral Engineers	7,190	9,619	9,133	7,102	1,262	3,079
Chemical				17,778	5,082	7,766
Civil				11,374	3,537	7,233
Mechanical				28,564	6,965	13,553
Electrical				15,348	5,934	12,082
Others				35,062	18,852*	29,556
Total All Engineers			114,116	115,228	41,632	73,269

(1) *Mining and Metallurgy*, Sept. 1941, United States.
(2) JOURNAL OF ENGINEERING EDUCATION, Dec. 1941, U. S. and Canada.
(3) JOURNAL OF ENGINEERING EDUCATION, Dec. 1944, U. S. and Canada.
(4) JOURNAL OF ENGINEERING EDUCATION, Jan. 1946, U. S. and Canada, Advance Data.
* = Includes 3,163 Graduate Students, all branches.

The increased interest in establishing mineral engineering school scholarships by industry will help to point more good men into this field. The recently expanded scholarship plan of the Coal Division is commendable. These scholarships should be increased in number and in scope so as to attract men not necessarily connected with the Mineral Industry.

I have a distinct feeling that education in the mineral engineering fields is on the verge of a new era where its importance to our rapidly developing scientific and industrial civilization will be more fully and properly appreciated. We as educators in this field should be prepared to develop our programs to meet the additional needs that are sure to come. In fact, all engineering education is undoubtedly on the verge of an extensive expansion and mineral engineering should fill its part in this program.

A Note on Foreign Service and the Foreign Student

By J. K. FINCH

Dean, School of Engineering, Columbia University

Engineering schools in the United States have long attracted small numbers of foreign students and it is quite apparent that the number of such students has been increasing in recent years and will probably be greater for a number of years to come. There is building up in the world, at least among the more progressive nations, a new nationalism. Until World War I the great nations sought power through military might. The struggle to control or strengthen economic resources is also still a major nationalistic goal. Yet it is becoming ever clearer, as the war has, indeed, made obvious, that the progress and survival of modern nations will rest primarily on the development and maintenance of a high level of scientific, engineering and industrial leadership. Technological accomplishment—from discovery and invention to production and transportation—has been the vital factor in winning the war and, clearly, will be the basis for higher standards of life and living in the era of peace for which we all hope. This new, technological nationalism not only influences the coming of foreign students to our shores but has important implications in engineering education.

In the first place, many American students are apt to feel that there are certain to be great opportunities for foreign service, opportunities to aid in rehabilitating war torn areas or in inaugurating, in those countries where industrialization and power are still in their infancy, the new age of power and machinery. A calm and unbiased appraisal of the situation appears to indicate no major changes in prospects along these lines.

American engineers have served in the past and made notable contributions in foreign lands. American mining engineers, for example, were at one time active in South Africa. Note, however, that they were not young engineering graduates. On the contrary, they were mature, experienced experts who were called in as consultants to aid in establishing new operations, giving to British personnel the "know-how," and, when their work was finished, they came home. South Africa has not offered a fertile field for young mining graduates. Neither has China or Russia, and neither will Turkey. The Chinese, the Russians and the Turks are interested in building up their own technological resources and personnel. They will seek consulting advice but they offer no special opportunities for the young American engineer. In fact, it has become difficult for American engineers to enter and

to practice in many foreign countries unless they are willing to give up their American citizenship and give their lives and fortunes to foreign soil.

On the other hand, there have been and there again will be American firms which will undertake either the sale of American products or the construction of industrial or public works abroad. The young American engineer, however, who undertakes such service should understand clearly that he must either plan to make his career in such foreign service or simply mark off to general experience and "seeing the world" the few years which he may plan to spend in such service. In general, the American graduate who has had, say, two or three years of foreign service, will find, when he attempts to get started in the United States, that he is in about the same position as the new graduate. American employers give little or no experience credit for service abroad.

Boiled down to its fundamentals, therefore, it is the task of the American engineering school to educate engineers for service in the United States and any attempt to set up special courses for foreign service would be a waste of time and effort. This is not to say that the one group which should receive some consideration, those young men who hope to enter the foreign service of an American company, would not benefit by taking some of the courses which are now being organized in our leading universities under the direction of an "Institute of Foreign Affairs" or some similar division. Such courses on the history, culture, background and economics of foreign countries would be extremely valuable to the foreign representative of an American company. But the young American engineer with such service in mind should, first of all, know where he is to operate and should add this training to a sound fundamental engineering course. There is, as we have attempted to show, little demand or need for, and there is, in fact, no such thing as an engineering education especially adapted to and designed for foreign service.

When we turn to the needs and wants of foreign students who come to the States for engineering study, this latter statement becomes clear. Our first thought, in planning programs of study for, and in guiding, foreign students, is, quite naturally, that we must teach them how we do things in the United States. In fact it is very commonly their own wish and desire to become familiar with American engineering standards, practices and methods. Yet this is, unquestionably, the wrong approach—and for two reasons. There are very few countries in the world where engineering works comparable to those in the United States either could or should be built. Great North American engineering accomplishments—our great bridges, dams, tunnels, factories, buildings, parkways, etc.—are of little interest to the student from, say, Costa Rica or Turkey. In fact, undue attention to these record-breaking achievements is very apt to be not only a waste of time but most irritating to the student who comes to us from a land where such costly and gigantic works are not within even the bounds of wishful thinking.

Similarly, many American practices would be completely uneconomic and unintelligent in other countries. For example: Any highway span up to 150 feet or thereabouts would normally, in the States, be carried by a girder bridge. Some form of truss or light tied-arch would be used up to, say,

five or six hundred feet or more. Yet really short span suspension bridges, spans of only fifty to eighty meters, are commonly used in isolated areas of South and Central America where no facilities for bringing in girder or truss parts are available and skilled erection crews are unknown. We are liable to lose patience with the foreign student who makes a proposal of this kind—at complete variance with American practice—yet he may be on the right track.

The writer still recalls the case of one of our graduates who, called upon to plan storage facilities for construction materials in Greece, designed the usual light frame building with corrugated iron sides and roof. A French friend put him right. Timber and steel had to be imported. Stone was at hand and labor cheap. Build your walls, he said, of dry rubble and use only the inescapable minimum of your costly imported materials.

In other words, engineering design in any country is determined by the materials and labor available. In the United States we have adapted our design, construction and manufacturing methods to our own peculiar conditions of labor and material costs. We are apt, however, to lose sight of the fact that, in other countries, these basic factors which determine design will probably be quite different and it is, therefore, a waste of time to insist that a foreign student become thoroughly familiar with American standards and methods. What the foreign student needs is, quite obviously, the best that we can give him in fundamental engineering analysis and training. When he returns to his own land, his problem will be that of using to the best advantage those peculiar and special resources, material and human, which are characteristic of his own country.

The emphasis with foreign students, therefore, must be on basic analysis and principles. They will very often ask us: Why do you do this in this way? and, in many cases we may be put to it to find an adequate answer. We, too often, teach standard American practice and too seldom attempt to look back of such practice to the principles, economic and other, on which it is based. The foreign student, therefore, may, unconsciously, be aiding American engineering education for he makes us think in terms of fundamental principles and forces us to go back of current practice and give consideration to the basic factors on which good design and good practice must rest.

Report of the Engineering College Research Association's Committee on Legislation

By C. E. MacQUIGG, *Chairman*

The Engineering College Research Association's Committee on Legislation consisting of Deans Ivan C. Crawford, F. M. Dawson, H. P. Hammond, C. E. MacQuigg and Thorndike Saville presents the following statement:

The Committee testified in October, 1945, at hearings before the Joint Subcommittees of the Senate on the Kilgore and Magnuson bills. A number of meetings have been held since that time and the Committee has been in constant correspondence regarding the form of legislation. Committee members have attended numerous conferences working with others representing the supporters of the type of legislation favored in the Bush report "Science, the Endless Frontier."

After much effort to bring together the various ideas embraced in the two bills, a bill S.1850 was prepared and was introduced on February 21 by Senators Kilgore, Magnuson, Johnson of Colorado, Pepper, Fulbright, Saltonstall, Thomas of Utah, and Ferguson. One of the subcommittees, namely that of the Committee on Commerce, has reported favorably on this bill and by the time this report appears, the Subcommittee of the Senate Military Affairs Committee may also have reported favorably. Favorable action by the Senate is hoped for. S.1850 now seems to represent the legislation upon which the largest number of adherents can agree. The following analysis covers the main points embraced in the bill.

Digest of S.1850—February 21, 1946

NOTE: This is the latest Science bill which the Committee has seen and presumably it is the last one which will be presented as a result of the conferences and compromises arranged by groups interested in the proposed legislation.

Purpose of the Bill. "To promote the progress of science and the useful arts, to secure the national defense, to advance the national health and welfare, and for other purposes." The Act will be known as the "National Science Foundation Act of 1946." . . . "The Congress declares it to be the purpose of this Act, among other things, to provide support for scientific research and development, to enable young men and women of ability to receive scientific training, to promote the conservation and use of the natural resources of the Nation, to correlate the scientific research and development programs of the several Government agencies, to achieve a full dissemination of scientific and technical information to the public, and to foster the interchange of scientific and technical information in this country

and abroad. The Congress further finds it essential for these purposes to create a central scientific agency within the Federal Government."

The Administrator shall be appointed by the President with advice and consent of the Senate, at $15,000 per year. Before the appointment is made the President shall consult with and receive the recommendations of the National Science Board. The Administrator shall administer the Foundation. A Deputy Administrator is to be appointed by the Administrator at $12,000.

The following Divisions are established in the Foundation: Mathematical and Physical Sciences, Biological Sciences, Social Sciences, Health and Medical Sciences, National Defense, Engineering and Technology, Scientific Personnel and Education, Publications and Information; and such added Divisions, not to exceed three in number, as the Administrator may establish after receiving the advice of the Board. "The functions of each division shall be prescribed by the Administrator after receiving the advice of the Board, except that until the Administrator and the Board have received general recommendations from the Division of Social Sciences regarding the support of research through that Division, support of social science research shall be limited to studies of the impact of scientific discovery on the general welfare and studies required in connection with other projects supported by the Foundation. Each division shall be headed by a Director, who shall be appointed by the Administrator and shall receive compensation at the rate of $12,000 per annum."

Number and compensation of assisting personnel, other than those described in the Act, shall be fixed by the Administrator and in accordance with civil-service laws "except that, when deemed necessary by the Administrator for the effective administration of this Act, expert scientific, technical, and professional personnel, including part-time personnel, may be employed without regard to civil-service laws, and their compensation fixed without regard to the Classification Act of 1923, as amended."

"The Administrator, in exercising his authority under this Act, shall consult and advise with a National Science Board and, through the Directors of the several divisions, with divisional scientific committees, on all matters of major policy, program, or budget. The Board shall consist of nine members appointed by the President, by and with the advice and consent of the Senate, from among persons who are especially qualified to promote the broad objectives of this Act, plus the chairmen of the several divisional scientific committees. The scientific committee for each division, except the Division of National Defense, shall consist of not less than five and not more than fifteen members appointed by the Administrator, with the advice and approval of the Board, except that the initial members of each such divisional scientific committee shall be appointed by the Administrator with the advice and approval of the Board members appointed by the President."

The National Defense Division shall consist of not less than forty persons, one-half to be civilians, the others to be equally divided between heads of services, divisions, bureaus or offices of the War and Navy Departments as named by the respective Secretaries of War and Navy. The Division of National Defense shall have a five-man executive committee consisting of the

Chairman of the divisional scientific committee, as chairman; two civilians and one each from the War and Navy Departments.

"Each divisional scientific committee shall be reasonably representative of the major scientific interests and functions of its division. Members of the Board appointed by the President and members of the divisional scientific committees appointed by the Administrator shall serve for three-year terms, except that (1) at least one-third of such members originally appointed shall be appointed for one-year terms, and at least another third for two-year terms, and (2) any member appointed to fill a vacancy occurring prior to the expiration of the term of his predecessor shall be appointed for the remainder of such term. No person thus appointed to serve as a member of the Board or any divisional scientific committee shall be eligible again to serve as a member of the same group until the expiration of one year after his term has expired, except that a member appointed for a term of less than three years may be appointed for a succeeding three-year term.

"(b) The Board and each divisional scientific committee shall annually elect its own chairman from among its own members, and shall devise its own rules of procedure. The Board and each such committee shall meet at the call of its own chairman or at such times as may be fixed by itself, but not less than six times each year, including at least once each calendar quarter. Vacancies in the membership of the Board or any divisional scientific committee shall not impair the authority of the remaining members to execute its functions, and a majority of the members of the Board or any divisional scientific committee as constituted at any given time shall constitute a quorum."

An executive secretary shall be appointed by the Board at a salary of $12,000 and the necessary expenses of the divisions shall be paid by the Administrator.

"(c) The Board shall continuously survey the activities and management of the Foundation, and shall periodically evaluate the achievements of the Foundation in accomplishing the objectives of this Act. Each divisional scientific committee shall survey continuously the scientific field which it encompasses, shall undertake to determine the specific scientific needs of such field, and shall evaluate proposed programs and projects. The Board and each divisional scientific committee shall, upon its own initiative or upon request by the Administrator, make appropriate recommendations and reports relating to its duties and findings. The Board and each such committee shall have full access to all information in the possession of the Foundation.

"(d) The Administrator shall render an annual report to the President and Congress, summarizing the activities of the Foundation, together with such recommendations as he may deem appropriate. The Board shall annually and at such other times as it deems necessary, make such recommendations to the President and the Congress as in its opinion will further the objectives of this Act. The annual report shall include such independent recommendations concerning the budget, organization, and management of the Foundation, and such other recommendations as the Board and the divisional scientific committees may deem necessary to better effectuate the purposes of this Act. The annual report shall include whatever dissenting opin-

ions may be submitted for that purpose by individual members of the Board or of the divisional scientific committees. The Administrator shall, whenever requested by the Board or any divisional scientific committee, publish and disseminate widely any recommendations or reports prepared by the Board or such committee."

Board and divisional committee members shall receive travel expenses and compensation of fifty dollars per day, except those holding other offices in the Executive branch of the Federal Government.

Board and divisional committee members shall be chosen without regard to politics and solely because of their fitness. Additional advisory committees or individuals may be added as necessary by the Administrator to further the purposes of the Act either without compensation or at fifty dollars per day and may serve without regard to the provisions of sections 109 and 113 of the Criminal Code (18 U.S.C. secs. 198 and 203) or Sect. 19 (e) of the Contract Settlement Act of 1944 "except insofar as such sections may prohibit any such person from receiving compensation in respect of any particular matter which directly involves the Foundation or in which the Foundation is directly interested."

Eighty (80) per cent of the funds are to be allocated in the following general way: 15 per cent to National Defense; 15 per cent to Health and Medical Sciences; 25 per cent to the States (including Alaska, Hawaii, and Puerto Rico), of which portion three-fifths is to be allocated on the basis of population and expended in tax-supported institutions; 25 per cent to be allocated to research in non-profit institutions.

"In making such contracts or other financial arrangements, the Administrator shall give each individual institution the widest latitude in its selection of individual research and development projects, but the Administrator shall not be required to expend funds in any institution unless it submits proposals for the expenditure of such funds which the Administrator finds to be consistent with such general program and standards as he may, after receiving the advice of the Board, establish in order to carry out the objectives and provisions of this Act."

The operations of the Foundation are supplementary and not to be construed as superceding or curtailing other scientific agencies of the Government.

"In all research and development activities financed or otherwise supported by the Foundation, the Administrator shall make every effort to eliminate restraints upon the free expression of scientific views and to insure full freedom in the exercise of creative talents, in the development of new ideas, and in the methods of research. Any person engaged in such research and development activities shall not be precluded from independently discussing, writing, or publishing his own views and conclusions relating to such research and development."

"The Administrator is authorized to award scholarships and fellowships to persons for scientific study or scientific work in any field of science, including but not limited to the mathematical, physical, biological, medical, and social sciences at nonprofit institutions of higher education, or other institutions, selected by the recipient of such aid, for such periods as the Administrator may determine, in the United States or in foreign countries. Persons shall be selected for such scholarships and fellowships solely on

the basis of aptitude, within the limits of such quotas as may be established to insure an equitable selection of such persons from among the States, the District of Columbia, and the Territories. Persons selected for such scholarships and fellowships may include employees of the Federal Government and such employees selected and detailed for scientific study or training shall not lose their status or seniority ratings for reason of absence from regularly assigned duties during the course of such study or training."

Provisions are made for the inventory of all current federally supported research and development projects, also a register of inventions, discoveries, patents and patent rights, in which the Government has an interest. The Administrator is also charged with broad activities in the dissemination of significant technical and scientific facts and developments.

Agencies contracting with the Federal Government for sponsored research must disclose to the Government all data ". . . on all inventions, discoveries, patents, patent rights, and findings produced in the course of such research or development, including such reports with respect thereto as may be required by such agency. Each Government agency, upon the request of the Administrator, shall make available to him such data and such reports with respect to research and development activities financed by such agency, as may be necessary for the purposes of this section.

"(c) All inventions, discoveries, or findings in which the United States (or any Government agency), now or hereafter, hold any rights, including patent rights, shall be made available to the public on a nonexclusive and on a royalty-free basis to the extent the United States or such agency is entitled to do so under the rights held by it. Except as provided hereafter in this subsection and in subsection (d), any invention, discovery, or finding hereafter produced in the course of federally financed research and development shall, whether or not patented, be made freely available to the public and shall, if patented, be freely dedicated to the public. The requirements of this subsection, to the extent that they require modification of contracts or other financial arrangements already entered into by the United States (or any Government agency) shall not go into effect until one hundred and twenty days after the date of enactment of this Act.

"(d) The head of any Government agency financing by contract, or otherwise administering, federally financed research and development activities, may, by stipulation in the contract or by other advance agreements with any organization, provide for the retention by the organization, or by the inventor, or by their assignees of such patent rights based on discoveries, inventions, or findings produced in the course of such research and development as the head of such Government agency deems fair and equitable, and consistent with the national interest: PROVIDED, That (1) the head of such Government agency shall, before entering into any such contract or agreement, make a finding that the agency has made every reasonable effort to arrange for the conduct of the necessary research and development without entering into a contract containing such provision; (2) the organization shall contribute or shall have contributed substantially to the development of the particular inventions, discoveries, or findings for which patent rights are retained

through earlier or current research and development activities financed by the organization; (3) in every case, the contract or agreement shall provide for at least an irrevocable, nonexclusive, royalty-free license for governmental purposes to the United States; and (4), in the case of any nonprofit organization, the head of such Government agency further determines (A) that the research and development is essential in the field of national defense or in such other fields as the President may specify for such purpose, and (B) that the patent rights retained will not be used to serve the special benefit of any organization conducted for profit or of any individual, and will be made available or licensed to applicants on a nonexclusive, uniform, and reasonable royalty basis.

"In the administration of the provisions of this subsection, the head of any Government agency shall be guided by such rules and regulations as the President may deem necessary and prescribe by Executive order.

"(e) The Administrator shall make a quarterly report to the President and to the Congress concerning contracts and agreements containing the provisions authorized by subsection (d). This report shall include a list of all contracts and agreements containing such a provision entered into by any Government agency during the preceding quarter, the reasons supporting the approval of such provision in each case, the amount of Federal funds expended or to be expended under each contract or agreement containing such a provision, the name of the organization with which the contract or agreement was made, and the general nature of the patent rights reserved for private use in each case. The report shall also include a list of all inventions, discoveries, or findings in which patent rights were permitted to be retained pursuant to the provisions of subsection (d) and which were first recorded or finally authorized during the preceding quarter, identification of the contract or agreement under which such inventions, discoveries, or findings were produced, and the nature of the rights retained. The report shall also include the Administrator's recommendations, if any, for such further Executive or legislative action as he may deem necessary.

"(f) Notwithstanding any other provision of this Act, the President, or any person designated for that purpose by him, may exempt from the requirements of this Act relating to dedication to the public, publication, dissemination, making available, or reporting information, data, patents, inventions, or discoveries relating to or produced in the course of federally financed research or development or in which the United States holds any rights, if and so long as the President or such designated person determines that such exemption is essential in the interest of national security."

Since the patent provisions of the Kilgore Bill have been a matter of controversy for several years, the text of the Bill in this respect is quoted above in full. The Committee believes that further negotiations on this detail of the Bill are not profitable and that resolving of the controversial matters must go to the Congress.

Provision is made to exempt the requirement for publicity of results of research if the President or his designee deems it necessary in the interest of national security.

With approval of the President and the State Department, reciprocal agreements may be made with foreign Gov-

ernments relating to interchange of technical and scientific information and co-operation in international research activities. Travel to international congresses is authorized.

An Interdepartmental Committee on Science is provided for and charged with the responsibility of gathering and correlating scientific data relating to the scientific research and development activities of the Federal Government. The Committee "shall study and evaluate such data in relation to the program of the Foundation and the scientific research and development programs of the other Government agencies; and shall make such recommendations to the Foundation and other Government agencies as in the opinion of the Committee will serve to aid in effectuating the objectives of this Act and other legislation providing for Federal support of scientific research and development. The Administrator, in consultation with the Interdepartmental Committee, shall, from time to time, make recommendations to the President for the achievement of maximum effectiveness in the conduct of all federally financed research and development."

"To enable the Administrator to carry out his powers and duties, there is hereby authorized to be appropriated annually to the Foundation, out of any money in the Treasury not otherwise appropriated, such sums as may be necessary to carry out the provisions of this Act. The funds appropriated to the Foundation, as herein authorized, and funds hereafter appropriated to any Government agency for scientific research or development, as herein defined, shall, if obligated during the fiscal year for which appropriated, remain available for expenditure for four years following the expiration of the fiscal year for which appropriated. After such a four-year period, the unexpended balances of appropriations shall be carried to the surplus fund and covered into the Treasury.

"The materials or equipment purchased by Federal funds or furnished by the Federal Government in connection with research and development activities shall be the property of the United States. The Administrator shall not, however, through the Foundation or its own employees, operate any laboratories, pilot plants, or other such scientific or technical facilities which he may acquire."

"The Office of Scientific Research and Development, and its constituent committees shall be transferred to the Foundation; together with such of the powers, functions, duties, personnel, property, records, funds (including all unexpended balances of appropriations, allocations, or other funds now available), contracts, assets, and liabilities as may be determined by the President. The National Roster of Scientific and Specialized Personnel shall be transferred from the Department of Labor to the Foundation, together with such of the personnel, records, property and balances of appropriations as have been utilized or are available for use in the administration of such roster as may be determined by the President. The transfers provided for in this subsection shall take effect at such time or times as the President shall direct."

Definitions of terms used in the Act are: "(a) 'Research and development' means theoretical analysis, exploration, and experimentation in any field of science (including but not limited to the mathematical, physical, biological, medical, engineering, and social sciences), and the extension of investigative findings and theories of a scientific or technical nature into practical

application, including the experimental production and testing of models and processes.

"(b) 'Federally financed research and development' means research and development conducted directly by the Federal Government and all other research and development financed in whole or in part directly by the Federal Government from funds designated for research and development, under a contract, grant, or other direct form of financial assistance for research and development.

"(c) 'Government agency' includes departments, independent agencies and commissions, corporations, and other instrumentalities of the Federal Government.

"(d) 'Organizations' includes State and local government agencies, corporations, partnerships, nonprofit institutions, and individuals.

"(e) 'Scholarships and fellowships' means stipends covering tuition and other fees, and such living, travel, and other expenses as the Administrator may determine."

Recent discussions of the legislation will be found in the following references:

"Science: A Problem in Legislation" by Oscar M. Ruebhausen, General Counsel, Office of Scientific Research and Development. The Record of the Association of the Bar of the City of New York February 1946.

"The National Science Foundation: S. 1850, Final Senate Bill" by Howard A. Meyerhoff, Executive Secretary, A.A.A.S. *Science* of March 1, 1946, page 270.

Having been in touch with the various developments resulting finally in S.1850, the Committee strongly urges members of The Society for the Promotion of Engineering Education and of the Engineering College Research Association to write to their senators and representatives demanding support of the Bill.

Specialist for Engineering Education Appointed

The engineering colleges of the country have been notified of the appointment of Henry H. Armsby as Specialist in Higher Education in the U. S. Office of Education (Assigned to Engineering Education). He will serve as a liaison officer between the Office of Education and the engineering colleges, and it is the hope that he may be instrumental in continuing the cordial relationships between them which developed during the conduct of E.S.M.W.T. The appointment of such an officer was recommended more than once by the E.S.M.W.T. National Advisory Committee and Regional Advisers, who felt that the continuation of these relationships would be of distinct value to all concerned.

The fundamental policy of the new office will be to serve the engineering colleges and governmental agencies in a spirit of mutual helpfulness, with no thought of coercion or control, and without infringing in any way on the responsibility or authority of any institution. The first objective will be to establish and maintain a clearing house for information and educational and statistical studies of value to engineering educators and at the same time to industrialists, government officials, and prospective engineering students. This will include giving information to the colleges regarding Federal activities of concern to them, and advising governmental agencies, industrialists, prospective students, and others concerning the programs and facilities of the engineering colleges, including their activities in research as well as in education.

Mr. Armsby is a graduate of Pennsylvania State College; was Field Coordinator of the E.S.M.W.T. program; and had previously served on the staff of the Missouri School of Mines and Metallurgy.

Sections and Branches

On Saturday, April 13, 1946 Ohio State University was host to the Spring meeting of the **Ohio Section** of the Society for the Promotion of Engineering Education. Sam B. Folk, chairman of the all-day meeting, presided at the morning session, and W. E. Nudd, Case School of Applied Science, vice chairman, was in charge of the afternoon meeting.

Following an address of welcome by President Howard L. Bevis of Ohio State University, the eighty members of the Society who were present heard President Harry S. Rogers, Polytechnic Institute of Brooklyn, speak on the topic, "The General Education of the Engineer," and J. Robert Van Pelt, Jr., who has charge of research education at Battelle Memorial Institute, speak on the topic, "The Engineering College and Research."

Following discussions and luncheon at the Faculty Club, Tell Berna, general manager of Machine Tools Builders Association, spoke on the topic,

"Industry Looks to the Engineer." During a business session following the meeting, officers elected for the Spring 1946 meeting, which will be held at Case School of Applied Science, were as follows:

Chairman: Prof. O. M. Stone, Case School of Applied Science; vice chairman Prof. Louis H. Rose, University of Dayton; secretary Prof. Wilson R. Dumble, Ohio State University.

The Eleventh meeting of the **Pacific Southwest Section** was held at the University of California, Berkeley, on February 22, 23, 1946. This was the first meeting since December 1941, the meeting proposals in the interim having been cancelled due to the crowding of transportation and hotel facilities. The attendance totalled 96 and represented eleven colleges and four junior colleges.

The first session occurred on Friday morning and was opened by Monroe E. Deutsch, Vice President and Provost of the University. In his remarks he not only gave a warm welcome to the visitors, but also made timely suggestions with respect to the limitation of enrollment which may be required to meet the great surge of returning veterans.

The meeting was organized into three regular sessions, an evening meeting and a tour of the laboratories. The following papers were presented:

When Is an Engineer Educated?, Baldwin M. Woods, University of California.

The Contribution of Engineering Schools and Engineers to the War Effort, M. P. O'Brien, University of California at Berkeley.

The Engineering Profession, a Definition. George L. Sullivan, University of Santa Clara.

What Should the Course in Applied Mechanics Contain in View of Present Technological Demands?, Lydik S. Jacobsen, Stanford University.

Jet Propulsion—Its Effect Upon Engineering Education, Frank J. Melina, California Institute of Technology.

Production Illustration, George Tharrat, Hollywood.

Contribution of Industrial Arts Training to the Development of Engineering Technicians, E. E. Ericson, Santa Barbara College, University of California.

Problems in the Development of Technical Institutes in California, Ralph Smith, San Jose State College.

Should Engineers Study Statistics?, Holbrook Working, Stanford University.

An informal luncheon was held each day at the College Women's Club. M. P. O'Brien was the speaker at the Friday luncheon. At the Saturday luncheon a series of U. C. Faculty men gave brief summaries of the research projects conducted at Berkeley during the war years. These talks were followed by an informal tour of the laboratories. Those present were first conducted through the 60 inch cyclotron. Besides the laboratory exhibits, there was an exhibit of the work of students in the several graphics courses. There was also an exhibit of precision grade surveying instruments in which appeared the modern type and the older type.

The annual business meeting was held at the Saturday morning session with approximately 35 voting members present. The following officers and committee members for 1946–47 were unanimously elected:

Chairman—Arthur Gehrig, Pasadena Junior College.

Vice-Chairman—Eugene Grant, Stanford University.
Secretary-Treasurer—E. D. Howe, University of California, Berkeley.
Executive Committee:
C. T. Wiskocil (retiring chairman).
Ward Austin, Marin Junior College.
Sidney Duncan, University of Southern California.
Franklin Thomas, California Institute of Technology.

It was decided to hold the next meeting at Pasadena, the tentative date being December 1946.

EVERETT D. HOWE,
Secretary-Treasurer.

The George Westinghouse Centennial

The George Westinghouse Centennial will be held in Pittsburgh, Pa., May 16 to 19, 1946, to commemorate the centennial of the birth of this great inventor and industrialist. "Science and Life in the World" is the theme of the centennial which comprises symposia and addresses arranged to provide an opportunity for scientists, engineers, and scholars to correlate present knowledge and to consider subjects for future research. Some of the topics and the speakers are:

Partners in Science, L. W. Chubb, Director of the Research Laboratories, Westinghouse Electric Corporation; *Explosive,* J. Ronert Oppenheimer, Professor of Physics at the University of California; *Power,* Enrico Fermi, Professor of Physics, University of Chicago; *Biological,* W. Edward Chamberlain, Professor of Roentgenology and Radiology, Temple University; *Chemical,* Hugh S. Taylor, Dean of the Graduate School, Princeton University.

Planning in Science, Vannevar Bush, Director, Office of Scientific Research and Development and President, Carnegie Institution; *Aviation,* Edward Warner, President of Interim Council, Provisional International Civil Aviation Organization; *Marine,* Emory S. Land, Vice Admiral, U. S. Navy, Retired; *Rail,* Martin W. Clement, President, Pennsylvania Railroad; *Transportation Planning in Urban Areas,* Harland Bartholomew, Harland Bartholomew Associates; *Automotive,* Charles F. Kettering, Vice President and Director, General Motors Corp.

Horizons in Communications, Frank B. Jewett, President, National Academy of Sciences; *Light and Life—Photosynthesis,* Cornelis B. van Niel, Professor of Microbiology, Stanford University; *High-Frequency Radiation and the Gene,* George W. Beadle, Professor of Biology, Stanford University; *The Microbe—Friend and Enemy of Man,* Selman A. Waksman, Professor of Microbiology, Rutgers University; *Molecular Architecture and Biological Reaction,* Linus Pauling, Chairman, Division of Chemistry and Chemical Engineering, California Institute of Technology.

Electric Power—The Foundation of Industrial Empire, Charles W. Kellogg, President, Edison Electric Institute; *Scientific and Engineering Progress—Insurance Against Aggression and Depression,* Karl T. Compton, President, Massachusetts Institute of Technology.

Friday afternoon will be spent at the Buhl Planetarium and Institute of Popular Science, Arthur L. Draper, Director. A trip through Mellon Institute of Industrial Research, Edward R. Weidlein, Director, is planned for Saturday morning.

New Members

ALDRICH, LAMAR, Instructor in General Engineering, Purdue University, Lafayette, Ind. W. J. Luzadder, Justus Rising.

ALEJANDRE, BLAS A., Head, Dept. of Physical Science, Philippine Military Academy, Manila. M. B. Potter, F. L. Bishop.

BABCOCK, WILLARD F., Assistant Professor of Civil Engineering, North Carolina State College, Raleigh, N. C. N. W. Conner, R. L. Cope.

BECK, NIELE C., Superintendent of Instruction, Parks Air College, East St. Louis, Ill. F. C. Parks, E. A. Vezeau.

BELL, WILLIAM G., Assistant Professor of Ceramics, Rutgers University, New Brunswick, N. J. A. F. Greaves-Walker, P. H. Daggett.

COLE, DAVID H., Associate in Mechanical Engineering, University of Illinois, Urbana, Ill. W. N. Espy, J. C. Miles.

COOLSEN, FRANK G., Assistant Professor of Economics and Business Administration, Rensselaer Polytechnic Institute, Troy, N. Y. W. F. Spafford, M. A. Hunter.

DANFORTH, HOWARD E., Instructor in Mechanical Drawing, Arlington High School, Arlington, Mass. C. J. Walsh, V. E. Howes.

FISCHER, EMIL C., Associate Professor of Architecture, The Ohio State University, Columbus, Ohio. W. C. Ronan, O. E. MacQuigg.

FISKE, DAVID L., Secretary, American Society of Refrigerating Engineers, 40 W. 40th St., New York City. Re-admission.

FLORCRUZ, PEDRO R., Philippine Military Academy, Malolos, Bulacan, Philippines. F. L. Bishop, Nell McKenry.

FOSTER, EDWARD W., Air Conditioning Dept., General Electric Co., 5 Lawrence St., Bloomfield, N. J. A. C. Stevens, F. H. Pumphrey.

GIFFIN, BERTRAND L., Instructor in Electrical Engineering, Oregon State College, Corvallis, Ore. A. L. Albert, F. O. McMillan.

KORAN, STEPHEN E., Assistant Professor of Mechanical Engineering, Youngstown College, Youngstown, Ohio. L. A. Deesz, F. L. Bishop.

HAZARD, CLIFTON T., Professor of Mathematics, Purdue University, Lafayette, Ind. R. G. Sturm, S. D. Chambers.

HUDSON, DONALD E., Assistant Professor of Mechanical Engineering, California Institute of Technology, Pasadena, Calif. F. C. Lindvall, Franklin Thomas.

KOENIG, JOHN H., Professor and Head, Dept. of Ceramics, Rutgers University, New Brunswick, N. J. P. H. Daggett, A. F. Greaves-Walker.

LEHMANN, MELVIN R., Assistant Professor of Industrial Engineering, Oklahoma A. & M. College, Stillwater, Okla. H. G. Thuesen, E. R. Stapley.

DEMATTOS, JOSE ZACHARIAS, AMARAL, Professor of Technical Drawing, Escola Nacional de Engenharia, Largo de Sao Francisco, Rio de Janeiro, D. F., Brazil. W. E. Street, F. L. Bishop.

MILLER, EDWIN L., Assistant Professor of Geology, North Carolina State College, Raleigh, N. C. J. L. Stuckey, R. L. Cope.

NASON, LEIGH, Field Editorial Representative, Pitman Publishing Co., New York City. R. F. Neale, A. C. Horsch.

NEUFFER, FRANK R., Dean, Evening College, University of Cincinnati, Cincinnati, Ohio. C. A. Joerger, W. C. Osterbrock.

OLSON, O. NEIL, Associate Professor and Head, Dept. Civil Engineering, Marquette University, Milwaukee, Wis. W. D. Bliss, J. F. H. Douglas.

PARR, KENNETH E., Instructor in General Engineering, Purdue University Lafayette, Ind. J. N. Arnold, W. J. Luzadder.

RAUTENSTRAUCH, ROBERT, Associate Professor of Aeronautical Engineering, North Carolina State College, Raleigh, N. C. T. E. Hyde, R. L. Cope.

REYNOLDS, RAYMOND W., Instructor in General Engineering, Purdue University, Lafayette, Ind. W. J. Luzadder, Justus Rising.

ROWLAND, WILLIAM G., Instructor in Civil Engineering, A. & M. College of Texas, College Station, Texas. W. E. Street, J. G. McGuire.

ROBINSON, SAMUEL M., Administrator, Webb Institute of Naval Architecture, New York 63, N. Y. Thorndike Saville, J. M. Labberton.

SHERMAN, VINCENT E., Instructor in Engineering Drawing, Purdue University, Lafayette, Ind. W. J. Luzadder, L. W. Thomas.

TAYLOR, WENDELL S., Assistant Professor of Mechanical Engineering, University of Oklahoma, Norman, Okla. E. F. Dawson, E. M. Sims.

THOMPSON, FRANKLIN H., Assistant Professor of Engineering Drawing, Purdue Univ., Lafayette, Ind. W. J. Luzadder, Justus Rising.

WALTER, JOHN A., Instructor in English, University of Texas, Austin, Texas. Roscoe Guernsey, Dana Young.

WYKOFF, GEORGE S., Professor of English, Purdue University, Lafayette, Ind. W. J. Luzadder, Justus Rising.

276 previously elected
33 this list

309 new members April 25, 1946

College Notes

Joseph W. Barker, dean of the School of Engineering at **Columbia University** since 1930, has resigned. Dr. Barker will become president of the Research Corporation, with headquarters in New York.

James Kip Finch, Professor of Civil Engineering and since 1941 associate Dean of the Faculty of Engineering, has been appointed to succeed Dr. Barker as dean.

John D. Kraus, Harvard University research scientist and inventor of several wartime engineering devices, has been named associate professor of electrical engineering at **Ohio State University,** effective July 1. Professor Kraus will specialize in teaching and research in communications engineering.

Andrey A. Potter*

When one has for a subject a man who has served this University so long, so faithfully and so efficiently as Dean Potter has, it is a real pleasure and a deep privilege to speak about him. I also wish to include Mrs. Potter and call to your attention that these two have been at the University for a few months over twenty-five years. This is their silver celebration at the University. It is capped by Dean Potter being the Acting President in these momentous times when peace has come to the world, accompanied by all the complexities that need to be solved not only here in our University community but in the world at large before security—real lasting security—can be made present everywhere.

During all these twenty-five years the characteristic of Dean Potter's that stands out most vividly is that he has served the University unselfishly, served it not only in the various engineering schools but in all its other departments. If ever we have met a man who placed "Service above Self" it has been Andrey A. Potter.

In a university, service is rendered by teaching and by research. However, both these functions cannot operate efficiently unless the administration creates a favorable atmosphere. Here is where an able dean or president makes his mark upon an institution. Here is where Dean Potter has achieved an outstanding accomplishment in so administering his high office that the teachers and investigators of Purdue have been encouraged to perform their daily duties in such happy circumstances that duties have become pleasures. Such stimulation of the staff cannot help but be reflected in the training accorded the students who carry the name of Purdue to all parts of the United States and to far distant places. When these trained students leave Purdue, many carry upon them the distinguishing stamp of Dean Potter. Truly the Potter has moulded the clay of the youth to the service of the country.

I am of course fully aware that during these twenty-five years, the main impress of the ability and scholarship and personality of Dean Potter has been upon the engineering schools, yet it is strikingly attested by many communications from the staffs of the other divisions of the University how outstanding has been the sympathetic understanding of Dean Potter in dealing with these other aspects of that complex whole which is indeed the University we call Purdue.

Speaking for many of the staff who have been privileged to perform their service under Andrey Potter as Dean of the Engineering Schools, it is a revealing aspect of his administration and leadership to have him say and also to see realized in his actions that he, the Dean, is not the arbitrary boss but the inspiring guide of his manifold staff. He really seeks to understand and visualize what his various teachers need in order to realize their best efforts toward the students in their classes, shops and laboratories.

Dean Potter is a true friend of us all and because of his understanding of the different personalities that comprise

* Celebrating twenty-five years of service at Purdue University, address gvien at the Purdue Memorial Union, December 10, 1945.

such a varied group as are in the engineering schools, coupled with his vision and knowledge of what are the aims and methods of higher education, he has been all these years the leader whom it has been a pleasure and an inspiration to follow.

This realization of the conditions for successful teaching has had a powerful influence upon the type and quality of the educational processes to which the students under his charge have been subjected. The result has been that the products of the engineering school of Purdue, the trained engineers, have gone out to occupy positions of responsibility in the world at large.

However, Dean Potter is never satisfied with a task well done—he strives to have it performed even better. This has been illustrated from year to year —and never more than in these changing months. The students in this post-war world must face new problems—and be trained to solve them with a wider viewpoint than ever before. Dean Potter has been the instigator of studies designed for just such a broadening of the student's education. The world must be in everyone's vision, not just one's country!

I have noted a regret at times on Dean Potter's part that his administrative duties have kept him from the research or the technical writing that he loved to indulge in during his earlier years. Perhaps this explains his deep sympathy and his careful planning for the support of research and writing on the part of his staff.

I have been speaking of Dean Potter and Purdue University. Indeed the two are synonymous to thousands of us of the faculty and among the alumni. But Dean Potter's talents for lasting friendship and constructive work have made his influence felt in the State of Indiana and throughout the Nation. He has served this University, this State, his profession and the country from one ocean to the other and from the North to the South. Everywhere he has been honored by those who worked with him until the mere cataloging of the offices he has held and the honors that have been bestowed upon him would encompass the width and the breadth of engineering education in these United States.

Mention should be made of Dean Potter's war work in the specialized education of thousands of men and women in Engineering, Science and Management War Training. This functioned mightily to implement the war effort with the materiel without which a war cannot be fought successfully in these technical times. Also on the peace side of the industrial scale weighs heavily his sagacious recommendations as Executive Director of the National Patent Planning Commission.

Frequently in the professional world of the Society for the Promotion of Engineering Education or of the American Society of Mechanical Engineers or the like, Andrey Potter is spoken of as "The Dean" or "The Dean of all Deans." However, Andrey Potter may be addressed, whether as President or Dean or friend, the very intonation and manner signifies respect and recognition.

But I want to pause a moment and emphasize that the most striking characteristic of Andrey Potter is his capacity for sincere and understanding friendship. Dean Potter has occupied many responsible positions and all his associates, whether in high or low stations in life, have felt and have ex-

pressed this sympathetic personal touch that is as rare as it is needed in these difficult days.

We often wait to say nice things about a man or a woman until what we say, he cannot hear. On this occasion we are expressing the fine attributes many of us feel about a man while he is well and flourishing.

* * *

So at this, the Silver Anniversary of your Deanship, when you are in the full flight of your distinguished career, let us all join in wishing for you, Dean Potter, a long continuation of the outstanding services that you have so skillfully rendered during these past twenty-five years!

R. NORRIS SHREVE,
President, Purdue University Club

The George Westinghouse Award in Engineering Education

The Society for the Promotion of Engineering Education announces the George Westinghouse Award in Engineering Education—an annual award of $1,000.00 for distinguished contribution to the teaching of engineering students. The award is sponsored by the Westinghouse Educational Foundation.

The George Westinghouse Award is to be made for the first time in 1946 under the following general conditions:

1. *Purpose.* To recognize and encourage outstanding achievement in the teaching of students of engineering.

2. *The Award.* An annual award of the sum of $1,000 and an appropriately engraved certificate is to be given at the annual dinner of the Society in June, to a recipient selected by the Society for the Promotion of Engineering Education. This award is made possible by the Westinghouse Educational Foundation.

3. *Fields.* Candidates may be teachers of any division of subject matter ordinarily taken by engineering students, including, besides the recognized divisions and subjects of engineering, such subjects as English, mathematics, physics and chemistry.

4. *Requirements.* In order to receive the award a person must have made a clearly discernible contribution to the art and science of teaching. He shall have established achievement in several of the following ways:

(*a*) Success as a teacher must be established both as to competence in subject matter and ability to inspire students to high achievement as demonstrated by the careers of former students.

(*b*) Improvement of the tools of, and conditions for, teaching. Evidence of such achievement may consist of subject matter (textbooks, etc.), courses or curricula, teaching, testing, and guidance techniques, laboratory or other teaching equipment, and other similar activities.

(*c*) Improvement of teaching through various activities, including the development of teachers in a department, contributions to the better preparation of teachers, promotion of cooperation with other types of educational institutions, or with industry, and the coordination of fields of subject matter.

(*d*) Improvement of teaching through the effect of personal inspiration and leadership.

While there will be no age limitations in making the award consideration will be given especially to the *younger men who show by their past record evidence of continuing activity as superior teachers and who are in the process of carrying on projects for the improvement of teaching in engineering.* To them the award may serve not only as a reward but as an incentive toward further work which the funds might make possible.

5. *Committee on Award.* The award will be made upon the recommendation of a Committee on Award, the members of which are appointed by the President of the Society for the Promotion of Engineering Education. One of the proper functions of this Committee will be to develop criteria for judging good teaching. These criteria, as they emerge, will become a part of the selection procedures.

6. *Nominations.* Nominations may be made by any person, organization or group. This year they will be received up to April 20. Nominations are to be made on forms available from F. L. Bishop, Secretary of the Society, University of Pittsburgh, Pittsburgh 13, Pa., and from members of the Committee. Nominations must be accompanied by documentary evidence supporting all statements and claims.

COMMITTEE ON AWARD

HOMER L. DODGE, *Chairman,* President, Norwich Univ., Northfield, Vt.

R. T. BIRGE, Physics, University of California, Berkeley, Calif.

W. OTTO BIRK, English, University of Colorado, Boulder, Colo.

J. W. CELL, Mathematics, North Carolina State College, Raleigh, N. C.

H. O. CROFT, Mechanical Engineering, State University of Iowa, Iowa City, Iowa.

H. E. DYCHE, Electrical Engineering, University of Pittsburgh, Pittsburgh, Pa.

H. P. HAMMOND, Dean, School of Engineering, Pennsylvania State College, State College, Pa.

W. R. WOOLRICH, Dean, College of Engineering, University of Texas, Austin, Texas.

H. S. ROGERS, *ex officio* President S.P.E.E.; President, Poly. Inst. of Brooklyn, N. Y.

C. A. POWEL, Representing Westinghouse Educational Foundation, Union Bank Building, Pittsburgh, Pa.

Mechanics Division

CHARLES O. HARRIS, *Chairman,*
Illinois Institute of Technology

The following problems are contributed by Professor Ferdinand L. Singer of New York University. They are somewhat more comprehensive than most problems in current textbooks on Mechanics and have been used as review problems. While they are somewhat harder than most of the conventional problems, it is felt that their interest to the Mechanics Division is primarily in the opportunity that they provide to learn of the work being done at other schools.

1. A particle has an initial velocity of 100 ft./sec. directed at 60° with x-axis. The components of acceleration are assumed constant at $a_x = -4$ ft./sec.^{2} and $a_y = -20$ ft./sec.^{2} Compute the radius of curvature at the origin and at a point B on the trajectory which is 40 ft. below the origin.

Ans. At origin, $r = 1530$ ft.
At B, $r = 1430$ ft.

2. Two railroad cars, A and B, are moving down a 3 percent grade. At a given instant car B, which weighs 32,000 lb. and is moving at 5 ft./sec., is 100 ft. ahead of car A, which weighs 48,000 lb. and is moving at 10 ft./sec. Car resistance is assumed constant at 10 lb. per ton. Car A overtakes and collides with car B on the incline. The coefficient of restitution is 0.4. Assume car B rolls 300 ft. further down the incline after impact and then 500 ft. along a level track before striking a bumper spring having a modulus of 40,000 lb./in. Determine the maximum deformation of bumper spring. Take g. as 32.0 ft./sec.^{2}

Ans. $s = 1.405$ ft.

3. Three short bars, A, B, and C, as shown below, are equally compressed by a plate which is to remain horizontal. Moduli of elasticity, maximum allowable stresses, cross-sectional areas, and coefficients of temperature expansion are tabulated below.

(a) Find amount and location of P to cause maximum allowable uniform stress in all bars.

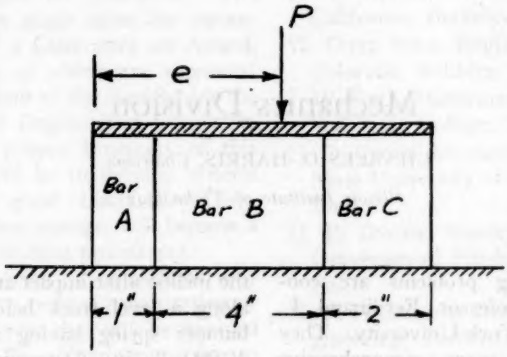
Ans. $P = 33{,}300$ lb., $e = 3.15$ in.

(b) Compute temperature change ΔT, P, and e, to develop maximum allowable stresses in bars A and B and zero stress in bar C.

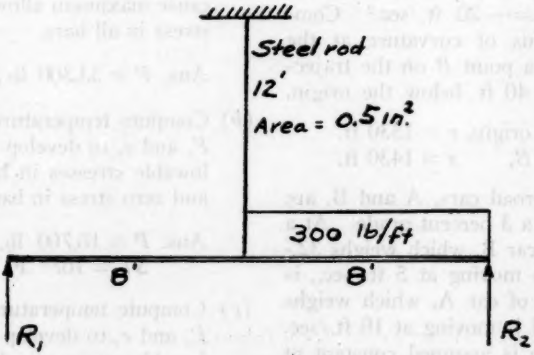
Ans. $P = 16{,}700$ lb., $e = 1.5$ in., $\Delta T = 167°$ F. drop.

(c) Compute temperature change ΔT, P, and e, to develop maximum allowable stresses in bars B and C and zero stress in bar A.

Ans. $P = 25{,}000$ lb., $e = 4.8$ in., $T = 250°$ F. rise.



Bar	A	B	C
E (psi).....	30×10^6	10×10^6	15×10^6
Allowable stress (psi) $\leqq$....	20,000	10,000	15,000
Area (in.^{2}).....	$\frac{1}{2}$	2	1
Coeff. of temp. exp. (in./in./°F.)	6×10^{-6}	8×10^{-6}	10×10^{-6}

4. A beam 16 ft. long carries a load of 300 lb./ft. over the right half of th span. As shown below, it is simp supported at the ends and by a ste rod at the center. The steel rod is 1 ft. long and ½ sq. in. in area. Th beam is of wood and is 4 in. wide by in. high. If $E_s = 30 \times 10^6$ psi and E $= 1.5 \times 10^6$ psi, determine the maxi mum stress in the rod and in the beam.

Ans. Rod: $S = 3020$ psi
Beam: $S = 585$ psi.